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REPRODUCTION OF THE LUMP-NOSED BAT (*CORYNORHINUS RAFINESQUEI*) IN CALIFORNIA

BY OLIVER P. PEARSON, MARY R. KOFORD, AND ANITA K. PEARSON

No one has described in detail the year-round habits and reproductive cycle of a North American bat. The important studies of Guthrie (1933*a* and *b*), Guthrie and Jeffers (1938), Reeder (1939), Miller (1939), and Wimsatt (1944*a*) deal with only a part of the reproductive cycles of the species treated, and the almost complete annual cycle of *Tadarida cynocephala* described by Sherman (1937) is marred by the disappearance of these bats at the critical period of copulation and ovulation. Study of the works cited above reveals that the usual pattern of reproduction of vespertilionid bats in eastern and central North America, as in Europe, is as follows: copulation in the autumn near the time of entering hibernation in caves, storage of sperm by both males and females during long periods of hibernation, and ovulation within a few days of emergence from hibernation in the spring. When brought from hibernation into a warm laboratory early in the spring, females will ovulate within a few days and become pregnant, even when separated from males.

It is clear that the most remarkable aspect of bat reproduction—sperm storage and delayed ovulation—is closely related to the phenomenon of hibernation. To us it seemed logical, therefore, to expect different reproductive behavior among bats living in a mild climate in California where long periods of hibernation were not known or expected. What reproductive modifications might be found that would accomodate a light and interrupted winter sleep?

The bat chosen for our study was the western lump-nosed bat, *Corynorhinus rafinesquei intermedius*. This subspecies ranges from southern California north and east into Oregon, Washington, Nevada, and Idaho. Other subspecies are found along the northwest coast and into Canada, south into Mexico and Lower California, and east nearly to the east coast. Except in a few instances noted otherwise, the specimens used in this report are of *C. r. intermedius* taken in central or northern California, chiefly in Marin, Napa, Lake, and Shasta counties. We have not followed Dalquest (1947) in calling specimens from Marin County *C. r. townsendi*.

We were fortunate in our pursuit of *Corynorhinus* to capture numerous specimens of each sex in every month of the year. This collection coupled with the important information made available by the banding operations initiated by

Mary Koford in 1946 has enabled us to reconstruct a fairly complete picture of the life history and reproductive behavior of this bat. One hundred and thirty-nine males and 288 females were dissected, and over 1500 bats were banded loosely on the forearm with small aluminum bird bands obtained from the U. S. Fish and Wildlife Service, and were released. Many of these banded bats were recaptured several times. Microscope slides were prepared of the reproductive organs of 100 males and 120 females. Almost all of these were prepared from tissues preserved in Bouin's fluid and embedded in paraffin.

About 70 specimens were kept in captivity for various periods up to six months. These were either kept in refrigerated rooms without food, or were kept at room temperature and were fed mealworms supplemented occasionally by percomorph oil. In general, *Corynorhinus* do not take well to captivity. It is difficult to induce them to feed themselves, and pregnant ones, even when eating well, abort or resorb their embryos. Most *Corynorhinus* can be induced to eat within a day or two after capture by pushing decapitated mealworms into their mouths. Once they have learned to take this food, and if the captor has time and patience, they can be hand-fed as many as 40 mealworms daily. Self-feeding can be encouraged by stringing mealworms on wires stretched along the sides of the cage, and eventually some individuals learn to eat mealworms out of a dish, but many never learn to feed themselves. Our most successful captives were ones that had been taught to feed themselves and were kept in a cage large enough to allow them to fly. Those kept in cold rooms survived well in almost-covered aquaria at 45° F. if drinking water was available.

Acknowledgments.—We are indebted to the following persons for much assistance in the pursuit and banding of *Corynorhinus:* Robert Bailey, Emma and Seth B. Benson, Wade Fox, Carl Koford, Philip Krutzsch, Robert Lewis, Eben and Ian McMillan, Brent Parrish, Bernice Riney, Todd Smith, and Lois Taylor. We are also indebted to Dr. Seth B. Benson for many helpful suggestions during this study and in the preparation of the manuscript.

General Habits

Accounts of the general habits of the big-eared bat may be found in Grinnell (1918), Hall (1946), and Dalquest (1947). It is a medium-sized vespertilionid bat weighing about nine grams (females slightly larger than males) and differs from most other bats in the relatively enormous length of its ears and in the possession of a large, rounded swelling which projects from each side of the snout and reaches well above the rostrum. The roosting habits of *Corynorhinus rafinesquei* are unusual in that adults are never found in cracks or crevices, but always hanging by the hind feet either free from a ceiling or along a wall or beam. Apparently this bat never crawls away from the spot where it first lands to roost, and, thus, is always found hanging in places open enough to be reached by flying. It will enter a building by crawling through a crack as small as two inches. *Corynorhinus* is always found in dark places in the daytime, the favorite roosting sites being attics, cellars, abandoned mine tunnels, and caves. It is a relatively late-flying species, and although it may fly about inside the roost for

some time before emerging, we have not seen it leave its roosting structure until after dark. Like many other species of bats, *Corynorhinus* may have a night roosting place where it rests after feeding. The night roosts with which we are familiar are in places similar to the day roosts, but may be places where *Corynorhinus* is not found during the day. The bats do not return to the day roost until almost dawn.

In the same night roosts with *Corynorhinus* we have found the following species of *Myotis: californicus, lucifugus, subulatus, thysanodes, volans,* and *yumanensis;* and in the same day roosting places: *lucifugus, thysanodes, yumanensis,* and *Macrotus californicus.* The *Macrotus* were present in large numbers in the daytime in the same tunnel with a nursery colony of *Corynorhinus.* On another occasion we found *Antrozous pallidus* coming to night roost in an attic used by a *Corynorhinus* colony while most of the adult *Corynorhinus* were out, but while the young were present. *Eptesicus fuscus, Myotis subulatus,* and *M. californicus* have been found hibernating in tunnels with *Corynorhinus.* In fact, two *subulatus* were actually in a cluster of 15 hibernating *Corynorhinus.*

Almost all banded *Corynorhinus* that were recovered were recaptured at the same place or within 1.5 miles of the place where they were first banded. We have found no evidence of long migrations. The most distant recapture was that of a young male found dead in an abandoned mine tunnel 20 miles from his birthplace.

Summer roosts.—The females and males have different roosting habits. In central California pregnant females congregate during the first half of April in colonies varying from a dozen individuals to as many as 200. The growth of the nursery colony is gradual and may extend well into May. These colonies remain more or less intact until late summer after the young are weaned. During this time the males lead a solitary existence.

We know of ten summer, or nursery, colonies of females of *Corynorhinus rafinesquei intermedius,* in addition to those reported in the literature. Six of these are in buildings, three are in mine tunnels or caves, and one alternated at times between two tunnels and a building. The bats ordinarily return to the same site year after year. Much of our work has been carried on in two nursery colonies in central California—one at Inverness, Marin County, and the other at Aetna Springs, Napa County. The Inverness colony, which averaged about 85 adult females, occupied at different times two buildings: an attic above a large, two-story carriage house, the second floor of which was seldom used, and the second floor of a barn-like structure used for storage of furniture. These two buildings were 1.3 miles apart. The Inverness colony was first banded in 1947 and has been visited frequently and banded each year since then. The Aetna Springs colony of about 60 females occupied an attic over the kitchen of a summer resort. During the summer months, while the colony was present, there was much noise in the kitchen and dining hall below, but the bats remained despite this. When disturbed by banding operations they sometimes moved to a mine tunnel one mile away. This colony was banded and studied on several visits in 1949, 1950, and 1951.

When a nursery colony is disturbed and moves to an alternate roosting place it moves at night, and on these occasions the females carry their young with them instead of leaving them behind as is the custom when the females go out to feed. One night we collected and banded 75 young after the adults had left, and by morning the adults had returned, picked up their young, and moved to their other roost 1.3 miles away. How all the individuals agree to move and manage to arrive at the same alternate roosting place with their young we cannot explain.

As a result of banding the Inverness and Aetna Springs bats, it has been possible to trace their reproductive history for successive years, to trace the growth and maturation of young in the wild, and to get preliminary information on longevity and survival. Unfortunately we have found neither of these colonies in the winter.

Seasonal activity.—Not only are the roosting habits of males and females different, but their patterns of activity are different. In considering their activity, it must be kept in mind that *Corynorhinus* and many other bats hibernate, in a sense, on many days in both summer and winter. When they return to their daytime roost after feeding, and fall asleep, their body temperatures may drop almost to that of the surrounding air, and, if the air is cold enough they become torpid—a physiological state indistinguishable from hibernation and differing from it only in that in actual hibernation the torpid condition may last for days or weeks. Conversely, under certain circumstances discussed below, the bats do not become torpid during the day, and are easily disturbed. These we refer to as being "awake" in contrast to the deep sleep of torpid bats. A compilation of temperature records made in bat roosts in all seasons indicates a tendency for bats of either sex roosting in places warmer than 62° F. to be awake and those at lower temperatures to be torpid. This does not mean that the bats are involuntarily torpid or wakeful, but probably that they seek different temperatures in different seasons of the year.

If a monthly chart is made listing the bats of each sex that are either awake or torpid when found, seasonal and sexual differences become apparent. Males tend to waken at night all year around; even in hibernation caves in midwinter many males fly about at night. In spring, summer, and autumn many males are alert and ready to fly even when discovered in the middle of the day. In fact, in July, August, and September one rarely finds a torpid male. Among females the inclination to hibernate is stronger, and in midwinter they are usually torpid both day and night. In February and March more of them become active at night and by the time they have gathered in large numbers in nursery colonies in April it is unusual to find females torpid even in the daytime. This wakefulness continues through the summer while the bats remain in the nursery colonies. September, when the males are coming into breeding condition, is the time when both males and females are least likely to be encountered in a torpid condition.

Winter roosts.—An important development during this study was the discovery of four places where *Corynorhinus* congregate in winter. Curiously, Californian bats had never been found assembled in winter in large numbers in caves as is the custom of most bats in the eastern United States. Most students of

Californian bats had assumed that when the large nursery colonies disappeared in the autumn the individual *Corynorhinus* scattered to abandoned buildings, mine tunnels, caves, hollow trees, or rock crevices, for in winter only stray individuals had been encountered. Because of the close relation between hibernation and the reproductive cycle, we have described below, in some detail, the wintering places and habits of *Corynorhinus*.

PARRISH CAVE.—The most populous winter colony was discovered in a cave on the north slope of Mount Lassen at Old Station, 4300 feet, Shasta County, California. The entrance is a large crater near Ice Caves, which are marked on the Halls Flat Quadrangle of the Geological Survey Topographic Sheet, 1939 edition. We have named this tunnel Parrish Cave after Brent Parrish of Old Station who first guided us to it. Like the numerous other caves in the region, Parrish Cave is a large lava tube running for many hundred feet close to the surface of the ground. Near the entrance the tunnel is about 30 feet in diameter, but it gradually narrows and the ceiling becomes lower until a man can no longer crawl through it. Conditions are such that probably all the *Corynorhinus* in the cave can be collected. We have found no other species in this cave.

Temperatures taken a few inches from hibernating bats in this cave varied on different occasions from 28.5° F. to 46° F. One cluster of 31 *Corynorhinus* was hanging from a ceiling where the air temperature was 30° F. A thermometer thrust into the center of the cluster registered 32° F. Many bats were hibernating only a few inches from icicles although warmer temperatures were available to them further back in the cave. The mean outdoor temperature in the coldest month in this region is well below freezing and temperatures below 0° F. are not infrequent.

The *Corynorhinus* begin to arrive at Parrish Cave late in October, and the colony reaches maximum size by January. Our data show that the females tend to arrive at the wintering caves earlier in the fall and remain later in the spring than do the males. The population reaches a peak in January, but does not remain constant for long, for small numbers of bats, predominantly males, continue to arrive at and depart from the hibernation caves throughout the winter. No new females, however, were found at Parrish Cave later in the winter of 1949–50 than January 14, and after this date there was a gradual decline in the population. The majority of the colony leaves the winter quarters by April. In three years the maximum numbers of bats that we found in Parrish Cave were as follows: 1948–49, males, 145 (9 removed), females, 56 (9 removed), total, 201; 1949–50, males, 69 (4 removed), females, 51 (4 removed), total, 120; 1950–51, males, 81 (7 removed), females, 30 (none removed), total, 111.

As when torpid in summer roosting places, the bats hang by their feet from the ceiling and walls with wings held tightly against the bodies, tails curled forward over the abdomens, and in most cases with their long ears coiled tightly against their heads. Some hang alone, but clusters of two or more are common. The largest cluster numbered 40. The composition of the clusters seems to be random with respect to age and sex. There is a tendency for those in clusters to have their ears erect while the ears of those hanging alone are coiled.

If the caves are visited at night one is likely to encounter a few flying bats,

while the rest are torpid. By noting the locations of the torpid bats in the afternoon and then returning the next morning, it will be found that a considerable number have moved during the night. Since large numbers are not awake at any one time, it must be concluded that individuals awaken, fly, and return to a torpid state in a short time, probably in less than an hour. On the afternoon of January 14, in one chamber of Subway Cave (see below), the locations of 56 torpid bats were marked by chalk marks on the ceiling with as little noise and disturbance as possible. The next morning 56 torpid bats were still in the chamber, but at least 17 had changed their locations. The temperature in this chamber of the cave was 34° F. Our records suggest that males tend to be more active than females.

Twelve males weighed in Subway Cave on February 3, 1949, averaged 8.36 grams. On April 2 the average weight of these twelve had dropped 0.64 gram to 7.72 grams. This loss probably represents the amount of fat required for existence at these temperatures (39° F. in the cave on February 3 and 50° F. on April 2). It would be interesting to have comparable figures for females to see if their lower activity in hibernation is reflected in less fat consumption, but enough figures are not available.

SUBWAY CAVE.—This too is a large lava tube and is situated only one mile NNW of Parrish Cave. We have considered it a separate wintering colony, however, because with only two exceptions there was no intermixing of the populations in any one year, and in successive years only a single individual of 305 bats banded in either cave returned in the next year to the other cave. Temperatures taken a few inches from hibernating bats in Subway Cave ranged on different occasions from 32° F. to 50° F. Warmer parts of the cave were easily accessible during cold periods, but were unoccupied. Numbers present were as follows: 1948–49, males, 59 (9 removed), females 34 (25 removed), total 93; 1949–50, males 32 (one removed), females, 7 (one removed), total, 39; 1950–51, males 18 (4 removed), females, 4 (none removed), total, 22.

It will be seen that this winter colony has decreased even below the size expected following our depredation in 1948. It is not unlikely that our removal of so many females at that time had a serious effect on the reproduction of those remaining. The banding of bats in their winter quarters may also cause more disturbance than one would expect. This was suggested by the behavior of the bats following one of our banding visits. All nine bats in the north branch of Subway Cave had moved to the south branch before our next visit two weeks later, and 15 of 44 in the south branch had moved to the north.

The fact that only one or two young bats of either sex appeared in Subway Cave in any winter since 1948–1949, when so many females were removed, suggests that a large proportion of the females and young making use of this cave in winter are a discrete colony both summer and winter. Very few unbanded adults of either sex appeared when the original colony was so nearly destroyed, so it seems likely that the adult male population also is derived largely from this same colony of females.

LAVA BEDS NATIONAL MONUMENT.—This is in Siskiyou County, California,

4800 feet. Many large lava tubes in this region are essentially similar to Parrish and Subway caves, but are slightly warmer in winter. We searched several of these caves near the headquarters buildings on February 3 and 4, 1949, and found about 30 torpid *Corynorhinus* scattered through various tunnels. No concentrations as great as those of Parrish and Subway caves were found, possibly because the bats may have been more evenly distributed through the great number of caves in the region.

MANHATTAN MINES.—Near Knoxville, Napa County, California, 2000 feet. The *Corynorhinus* listed below have been found wintering in three abandoned mine tunnels a few hundred yards apart in central California. Since there is frequent movement of the bats in winter from one tunnel to another, we have considered all three tunnels as representing a single wintering place. Several other tunnels nearby are seldom used by the bats in winter, and in most cases these tunnels are warmer than the occupied tunnels. Winter temperatures in the wintering tunnels varied from 33° to 52° F.

The roosting habits of these bats differed somewhat from those of the *Corynorhinus* in the Mt. Lassen caves, since we rarely found clustered bats at Manhattan Mines. The bats usually hung singly and were well scattered through the tunnels.

The winter population in the Manhattan Mines tunnels changed continually. At each monthly visit we found a considerable turnover, with unbanded bats appearing in the tunnels and banded bats disappearing. Here, as in the Mt. Lassen caves, the females were the first to arrive and the last to leave, and the males tended to be more active than the females. Also, there was considerable activity during the night, with six of 19 marked bats moving in one tunnel on November 11, 1949. The number of males in the Manhattan Mines tunnels dropped sharply after December. New females continued to arrive at the tunnels in considerable numbers in late February, unlike the behavior in the Mt. Lassen colonies. Even at the end of February, 22 of 27 female bats collected here were unbanded. Relatively few unbanded males appeared in the catch at this time.

The total numbers of *Corynorhinus* in the Manhattan Mines were as follows: 1949–50, 56 males and 127 females, total, 183; 1950–51, 9 males and 14 females, total, 23. The decrease in 1950–51 may have been due to climatic conditions (the winter was unusually warm and wet) or to our disturbance in the previous winter. We have removed only about 15 bats of each sex.

We have found that at different times of the winter the bats seek different portions of the tunnels in which to hibernate. One of the largest tunnels at Manhattan Mines has a long straight section which is characteristically cool, and a rear transverse section that is warmer. In November, 1949, when the outside temperature was 43° F., the bats were found mainly in the rear of the excavation, at a temperature of 55° F. In December and January the outside temperatures dropped below freezing and most of the bats present were then found in the front, well-ventilated part of the tunnel where the temperature was 33° F. The few bats in the rear of the tunnel (at 52° F.) were primarily males. Likewise, in nearby tunnels the females tended to roost in colder places than did males.

In spring no bats were found in the winter tunnels, but a nursery colony utilized a tunnel a few hundred yards away. Thirty-eight of the 140 females in this nursery colony had been banded in the winter tunnels. The females that were found unbanded at Manhattan Mines in late February were represented among the 38 banded bats in the same proportion as those that had been banded the previous November, so the bats from this summer colony must move somewhat independently during the winter. It is obvious that bats from several different nursery colonies occupy for short periods the same winter quarters at Manhattan Mines.

While it is probable that all *Corynorhinus* in northern counties such as Siskiyou and Shasta must resort to caves and tunnels in winter to keep their body temperatures, while torpid, above freezing, but at a low enough level to enable their fat stores to last until spring, in central California, in winter, not all *Corynorhinus* take refuge in tunnels and caves. Occasional individuals, usually males, are found in buildings, and up to three or four individuals, mostly females, may be found hanging torpidly in an otherwise deserted nursery roost throughout the winter. In most cases it is not known whether these individuals, who are exposed to colder temperatures than the bats in wintering tunnels in central California, fly in the evening, attempt to feed during mild weather, or remain torpid for long periods. One clue is provided by the record of a female *Corynorhinus* discovered in the Inverness attic. This was the attic that was occupied each summer by a colony of females and their young, and at other times by stray individuals. On the afternoon of December 14 a banded female was discovered torpid in one of about 12 narrow side passages that are seldom used by the bats. This bat did not move during the night of December 14. Forty-four days later, on our next visit to the roost, a banded adult female was torpid at precisely the same spot. We think it probable that this was the same female and that she had not moved for six weeks.

Evidence that *Corynorhinus* are active during the winter months in central California is provided by numerous records of their coming to night roosting places in Lake County at this time. For males we have records of activity in middle and late November, December, January, February, and early March. Outside temperatures at the time the bats arrived at the roosts in the evening ranged from 37° to 57° F. The repeated capture of a single night-roosting individual in January, February, and March indicates that some individual males are active throughout the winter. Records for females are less numerous and include middle and late November, January, and February. Outside temperatures varied from 47° to 57° F.

What food is used to support this winter activity we do not know. Flying insects are probably scarce, the fat stores of the females and young males probably are not capable of sustaining much activity, and the adult males accumulate little fat. Adult males have been taken in the Manhattan Mines on December 20 with no fat stored, yet banding records show that some adult males survive here at least until the next winter.

The Male

Anatomy of the male.—No attempt will be made to describe in detail the anatomy of the male. It is similar in most major features to that of other vespertilionids, such as those described by Robin (1881), Courrier (1927), Miller (1939), Matthews (1941), and Gopalakrishna (1948). There is little agreement among these authors as to terminology of the sex accessories, and Figure 1 is offered here to clarify the terminology that will be used in this paper. The most anterior of the accessory organs surrounding the base of the bladder are the ampullary glands or ampullae of Henle, glandular enlargements surrounding the ductus deferens. These probably correspond to the structures Miller (1939) called principal seminal vesicles in *Myotis*. The rest of the tripartite glandular mass surrounding the base of the bladder in *Corynorhinus* is considered to be prostate gland. Considerably posterior to the bladder, two pairs of Cowper's glands empty

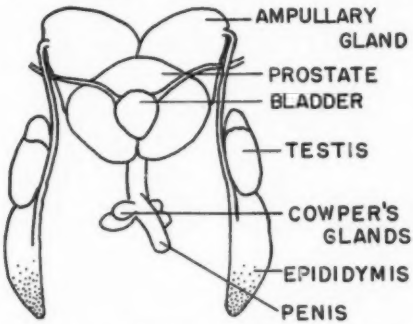

Fig. 1.—Diagram of reproductive organs of an adult male in winter.

into the urethra near the base of the penis. One pair of these glands is smaller than the other, as has been illustrated for a European bat, *Plecotus*, by Robin (1881). It is interesting that *Plecotus* and *Corynorhinus*, two genera that some taxonomists, on the basis of other features, have considered to be so closely related as to belong in the same genus, possess in common two pairs of Cowper's glands, a feature not found in other vespertilionids. Likewise, seminal vesicles apparently are lacking in both these genera.

The cycle in the testis.—The comments in this section are supported by the data presented in Figure 2 and Plates I and II, and in the legends to these illustrations. Careful study of Figure 2 is urged, for this one chart contains most of the critical information necessary for understanding the reproductive cycle of the male *Corynorhinus*.

During July and August the testes of young bats only two to three months old are usually slightly smaller than those of adults, and can be identified readily in sectioned material by the proportionately enormous amount of interstitial tissue present, and by the absence or scarcity of mitotic and meiotic activity in the

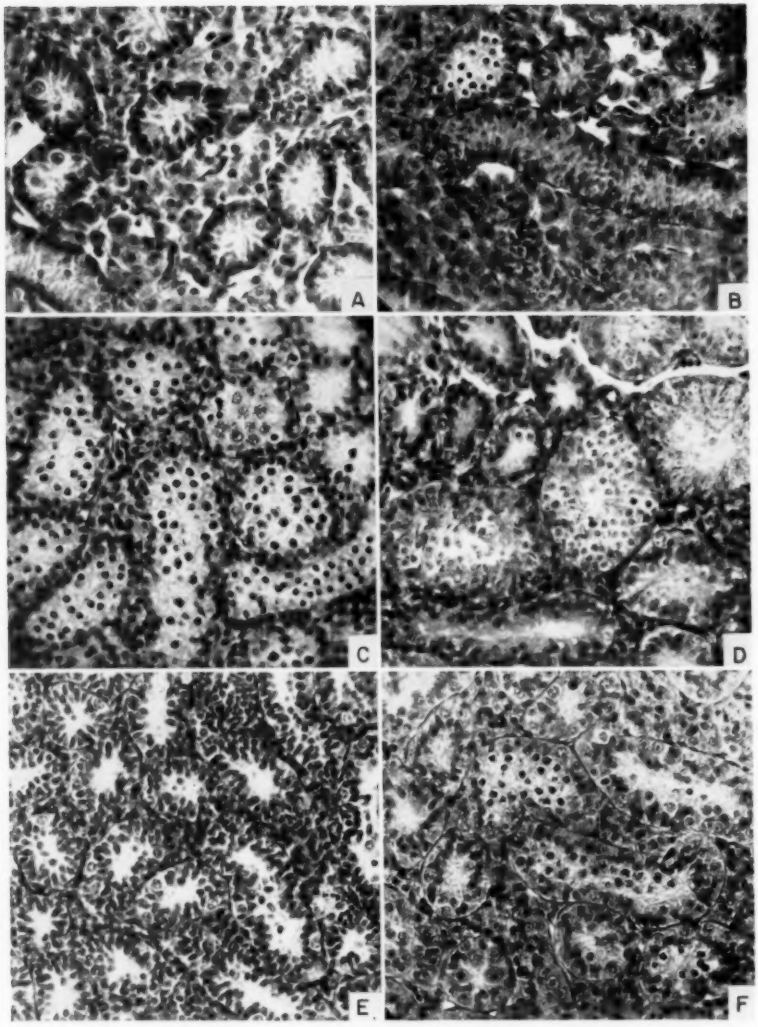

PLATE I

Testis cycle of young males. All 220×. A: one month old, June 30; interstitial tissue abundant; seminiferous tubules inactive, contain Sertoli cells and spermatogonia. B: about three months old, August 26; interstitial cells still conspicuous, synizesis stages in a few seminiferous tubules; C: October 1, considerable spermatogenic activity, many cells in synizesis and a few more advanced primary spermatocytes; diameter of tubules much less than in adults at comparable stage; interstitial cells decreasing. D: November 3; about 166 days old; several tubules contain spermatozoa, many quiescent; meiotic divisions absent; epididymis contained spermatozoa; sex accessories small. E: December 20; seminiferous tubules quiescent; interstitial cells small. F: April 15; many germ cells in synizesis; interstitial cells larger than in winter, sex accessories remain small.

seminiferous tubules (Plate I, A and B). In spite of their inactive appearance the testes of the young are enlarging gradually over the summer months and achieve their greatest length sometime between late August and October, a time when the adult testis is largest also. The young testis reaches a length of only 6 mm. (about 15 mg.) whereas the adult testis reaches a maximum of 13 mm. (377 mg.). Near the end of the period of enlargement the young testis exhibits a small amount of meiotic activity, and spermiogenesis proceeds, at least in some cases, to the formation of mature spermatozoa (Plate I, C and D). One banded young male four months old on September 17 contained dividing spermatogonia and synizesis stages, but no later stages; a second contained all stages up to late spermatids on September 25. A third banded young male had formed spermatids but no sperm by October 11, and a fourth had sperm in the epididymis and in some of the testis tubules on November 3. From the distribution of the points in Figure 2, it seems probable that not all young males ripen sperm in their first breeding season. One is impressed by how little spermatogenic activity is going on in the testes of young males in their first autumn: most of the tubules appear inactive in sectioned material, and the total quantity of sperm produced, judging by the numbers stored in the epididymides, is only a small fraction of that produced by the adults at this time. Because they produce so few sperm the young males are almost certainly sterile; the small size of their sex accessories probably also renders them sterile.

By November the testes of the young have regressed to the winter resting condition and measure about 4 mm. long. Throughout the winter the seminiferous tubules contain only Sertoli cells, resting spermatogonia, and occasionally a dividing spermatogonium. When synizesis stages reappear in April, the testis begins to enlarge again and this enlargement continues slowly during the late spring and early summer.

The summer adult testis is characterized by proportionately less interstitial tissue than in the young, and by the presence of great numbers of cells at synizesis (Plate II, A). It is not until after mid-August that large primary spermatocytes appear, and thereafter meiotic divisions and spermiogenesis proceed with great rapidity, accompanied by a spurt in testicular size. It is probable that in most individuals each of the cells in synizesis in late August passes in September through both meiotic divisions and converts itself into an advanced spermatid or a spermatozoon in less than three weeks. Thus, in an animal with a mating season lasting many months, all the reduction divisions and the metamorphosis of germ cells into spermatozoa are accomplished within a few weeks.

The busy September tubules of the adults are shortly exhausted, for in October they contain practically none of the vigorous, dividing younger spermatogenic stages, but are composed mainly of resting spermatogonia and of mature sperm or late spermatids that will be swept into the epididymis within a few days. This degeneration of the seminiferous tubules is accompanied by a dramatic shrinking of the testis to about one twenty-fifth its former volume and by the appearance of sperm in the epididymis. Note in Figure 2, however, that the peak of testis size is passed before the animal has become fertile. The earliest appearance of

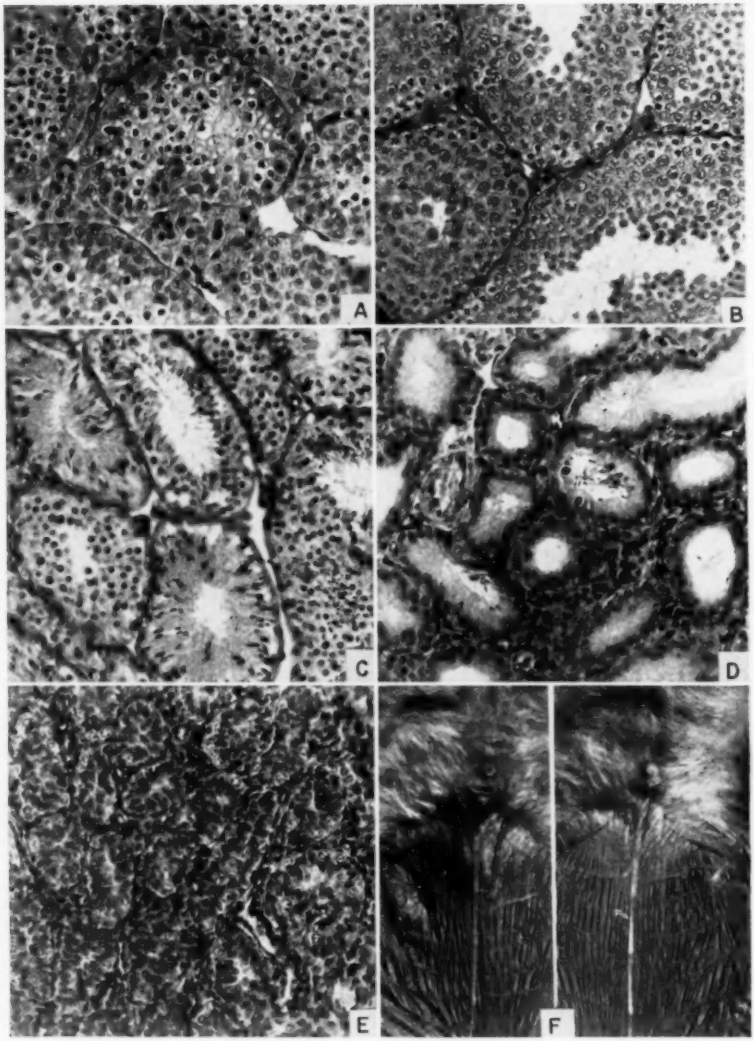

PLATE II

Testis cycle of adult males. All, except F, 220×. A: July 23; many cells in synizesis and conspicuous interstitial cells; sex accessories tiny. B: September 2; testes near maximum size and near peak of spermatogenesis; no spermatozoa yet in epididymis. C: September 25; near end of spermatogenesis; many spermatozoa and spermatids, but few younger stages; many spermatozoa in epididymis, accessories enlarging. D: October 5; spermatogenesis completed; interstitial cells shrunken, sex accessories large. E: December 20; interstitial cells at minimum size, tubules contain only Sertoli cells and spermatogonia; sex accessories large; copulation occurs with testis in this condition. F: Adult (left) and young (right) male in winter showing difference in size of the epididymides. About 1.5×.

sperm in the epididymis was September 25, and the latest sperm noted still in the seminiferous tubules was on November 3.

During the winter the small seminiferous tubules of adults are without lumina and contain only spermatogonia and Sertoli cells (Plate II, E). These testes average slightly larger than those of the young males and tend to be flabbier and more darkly colored. A more useful criterion for distinguishing between the two age classes during the winter is the thickness of the tunica vaginalis surrounding the testis. In sections, the tunica of adults is thicker than that of young, a difference that disappears at about the time that the testes resume growth in the spring.

Mitotic figures of spermatogonia during the winter are rare, but become increasingly common toward April, and the first synizesis stages become apparent at the end of April. There is some indication that these signs of more active spermatogenesis appear slightly later in adults than in young males.

The cycle in the epididymis.—The epididymides of young male *Corynorhinus* from November to March or April are less conspicuous than those of adults, for, although they project slightly into the interfemoral membrane (see Plate II, F), they are not swollen with sperm and frequently are smaller than the testes. In spite of the fact that the epididymides of the young sometimes contain small numbers of spermatozoa immediately after spermatogenesis, they apparently do not provide suitable conditions for sperm survival, for we have not found spermatozoa in the epididymides of young males after November. The adult epididymides, which during winter are frequently larger than the testes and always project conspicuously into the interfemoral membrane, shrink gradually during the fall, winter, and early spring, and by the end of April may be so small that they cannot be distinguished with certainty from those of young males. This decrease in size of the adult epididymis probably reflects gradual release of sperm in copulations during this period, coupled perhaps with a gradual leakage of sperm as has been demonstrated in laboratory and domestic animals denied opportunity to copulate. Even specimens as late as May 8 showed no evidence of phagocytosis of sperm in the epididymis.

With one exception in February, spermatozoa have been found in the epididymides of all adult males from November until April 27. Motile sperm cells were found in the epididymides of each of three males taken May 8, which is seven months after the sperm had left the testis. Specimens later than May 8 were not examined in such a fashion as to disclose whether the spermatozoa were living or dead. However, normal-appearing spermatozoa were present in sections of a few specimens until June 12, and a large clump of tailless spermatozoa was still in the epididymis of a specimen on August 25, eleven months after the spermatozoa had been formed.

The one exception mentioned in the paragraph above was a male banded in hibernation on January 14, 1949, and recaptured in the same cave February 12, 1950. It was thus known to be an adult. It was the only one of 40 banded adults present that did not have the epididymides showing conspicuously in the interfemoral membrane. Sections revealed no sperm in the epididymis and an appar-

ently normal testis. The sex accessories (5.5 mm.) were smaller than is usual for this date.

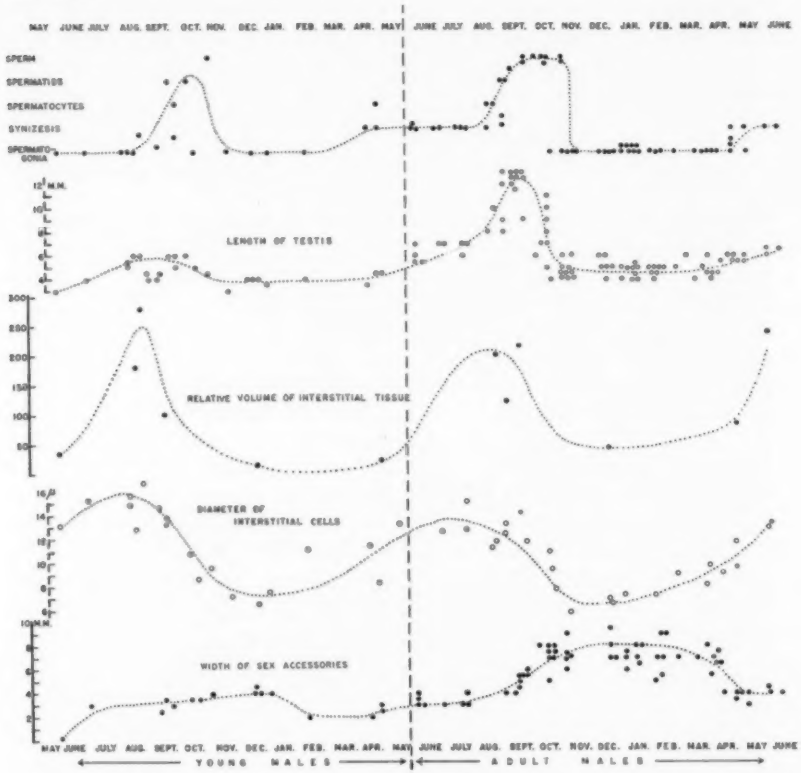
MAY JUNE JULY AUG. SEPT. OCT. NOV. DEC. JAN. FEB. MAR. APR. MAY JUNE JULY AUG. SEPT. OCT. NOV. DEC. JAN. FEB. MAR. APR. MAY JUNE
SPERM
SPERMATIDS
SPERMATOCYTES
SYNIZESIS
SPERMATOGONIA
LENGTH OF TESTIS
RELATIVE VOLUME OF INTERSTITIAL TISSUE
DIAMETER OF INTERSTITIAL CELLS
WIDTH OF SEX ACCESSORIES
MAY JUNE JULY AUG. SEPT. OCT. NOV. DEC. JAN. FEB. MAR. APR. MAY JUNE JULY AUG. SEPT. OCT. NOV. DEC. JAN. FEB. MAR. APR. MAY JUNE
YOUNG MALES
ADULT MALES

FIG. 2.—The reproductive performance of male *Corynorhinus* in their first and in subsequent years. Each circle represents a single bat. Specimens recorded as young males were less than 12 months old, those recorded as adults were more than 12 months old. In the uppermost curve each male whose testes were sectioned is represented by a single circle marking the *most advanced* spermatogenic stage that was *common* in the sections of that testis. Although a specimen from late September with many sperm in the seminiferous tubules might have numerous cells in each earlier stage, only one point would be put on the graph, at the sperm level. The entry "Spermatocytes" represents in every case post-synizesis prophases, for meta-, ana-, and telophases of the first and second meiotic divisions proceed so rapidly that, in every case in which these stages were common, spermatids were also common, so such testes would be entered under spermatids.

The cycle in the sex accessories.—The cycle in the accessory glands was observed by recording the greatest distance across both ampullary glands as they are revealed by reflecting the bladder posteriorly. Similar changes in the size of the prostate gland occur at the same time, but were not measured. The accessories undergo a slight but definite enlargement in young males in their first autumn

(Fig. 2). The enlargement occurs at about the same time as in adults, but is not nearly as great, and, judging from a single banded February juvenile, recedes sooner than in the adults. The accessories remain small through the spring and summer, begin to enlarge to the adult level in August, and achieve their maximum late in October or early in November near the beginning of the breeding season. Despite the regression of the testis the accessories of adults remain large throughout the winter and are conspicuously larger than those of young males until early April, when the adult accessories regress almost to juvenile size.

Determination of age of males.—In the absence of appreciable wear on the teeth, it has been necessary to resort to other criteria for determining the age of specimens. These are listed below and are the ones used for determining the age of specimens represented in Figure 2. The accuracy of the method was checked by examination of numerous banded specimens of known age. It has only been possible to "age" unbanded specimens up to one year. After that they are all combined as adults, meaning that they are one or more years old.

June through August

Young	*Adult*
Fur grayish	Fur brownish
Finger joints swollen, knobby	Finger joints not as swollen as in young
Usually in nursery colonies	Solitary
Testes with much interstitial tissue	Testes with normal amount of interstitial tissue
Seminiferous tubules without or with little meiotic activity	Seminiferous tubules with much meiotic activity

September and October

Young	*Adult*
Testes less than 7 mm. long	Testes more than 7 mm. long, or if smaller containing many exhausted seminiferous tubules and associated with ampullary glands more than 5 mm. across
Ampullary glands less than 5 mm. across (see adult)	Ampullary glands more than 5 mm. across, or if smaller associated with a testis showing much spermatogenic activity
Seminiferous tubules smaller than in adults and seldom showing maximum spermatogenic activity	

November through March

Young	*Adult*
Epididymis small and inconspicuous in interfemoral membrane	Epididymis large and conspicuous in interfemoral membrane
Sperm scarce or absent in epididymis	Sperm abundant in epididymis
Ampullary glands less than 5 mm. across	Ampullary glands more than 5 mm. across
Tunica vaginalis usually less than 30 micra thick	Tunica vaginalis usually more than 30 micra thick
Considerable subcutaneous fat	Less subcutaneous fat than young

April and May

As the adult accessories diminish and the sperm disappear from the epididymis, it becomes increasingly difficult to distinguish young from adults, and in May, when the young are almost 12 months old, it is frequently impossible to distinguish between the two age groups.

The interstitial tissue of the testis.—The most remarkable feature of reproduction in male *Corynorhinus* is the unusual time relationship between spermatogenesis, copulation, and growth of the sex accessories. Inasmuch as synchronization of these phenomena in mammals is believed to be achieved by production of androgens, and since the interstitial tissue of the testes is thought to be the source of these hormones, we have devoted considerable attention to it.

In most species it is impossible to divorce spermatogenesis from accessory growth because these two processes occur at the same time. In adult *Corynorhinus*, however, considerable spermatogenic activity occurs for three months before the accessories (prostate and ampullary glands) begin to enlarge. There is then a burst of spermatogenesis and spermiogenesis in September accompanied by growth of the accessories, but the accessories do not reach full size until the end of October, at a time when the seminiferous tubules are exhausted and the testis has atrophied almost to its winter minimum (Fig. 2). In other words, the accessories do much of their growing at a time when the testis is shrinking rapidly. Furthermore, the accessories remain large throughout the winter, while the testis is obviously quiescent, and only begins to regress in the spring at the very time when the testis resumes its growth. Copulation occurs only while the accessories are large—in other words, while the testes are small. Such an asynchronism of the usual reproductive processes presented an unusual opportunity to study the role of the interstitial tissue, and this we have attempted to do in the following measurements and experiments.

In Figure 2 will be found a graph of the measurements of interstitial cells of the testis from birth through the first year, and also for a full adult year. Each point is the average diameter of many cells of a single individual; each cell was measured along its longest and shortest axes and the two measurements were averaged. It will be seen that completely "asexual" young males only three months old have larger interstitial cells than do adults, that the cell size of the young males decreases at about the time that the "incomplete" growth of the accessories occurs, that the interstitial cells then enlarge at a time when the accessories are again small, and that the final growth of the accessories to full breeding condition in the adult is accompanied by a rapid decline in the size of the interstitial cells. Copulation occurs throughout the autumn and winter months when the interstitial cells are small (Pl. III). It appears, therefore, that if there is any direct relationship between the size of interstitial cells and these sexual conditions it is an inverse one; that if large interstitial cells secrete a hormone it is an inhibitory rather than stimulatory one. The inverse relationship of the sex accessories and interstitial cell curves could also be explained by assuming that the large plump cells are less secretory than small shriveled ones, or that secretion is stored in the large cells and is released at the time that the cells shrink in the fall. These two possibilities do not fit with the usual concepts of cell secretion.

It should be noted that the testicular and accessory cycles of *Corynorhinus* described above differ considerably from those of *Pipistrellus* and *Eptesicus* described by Courrier (1927).

Because of the enormous changes in size of the testes at different seasons, due

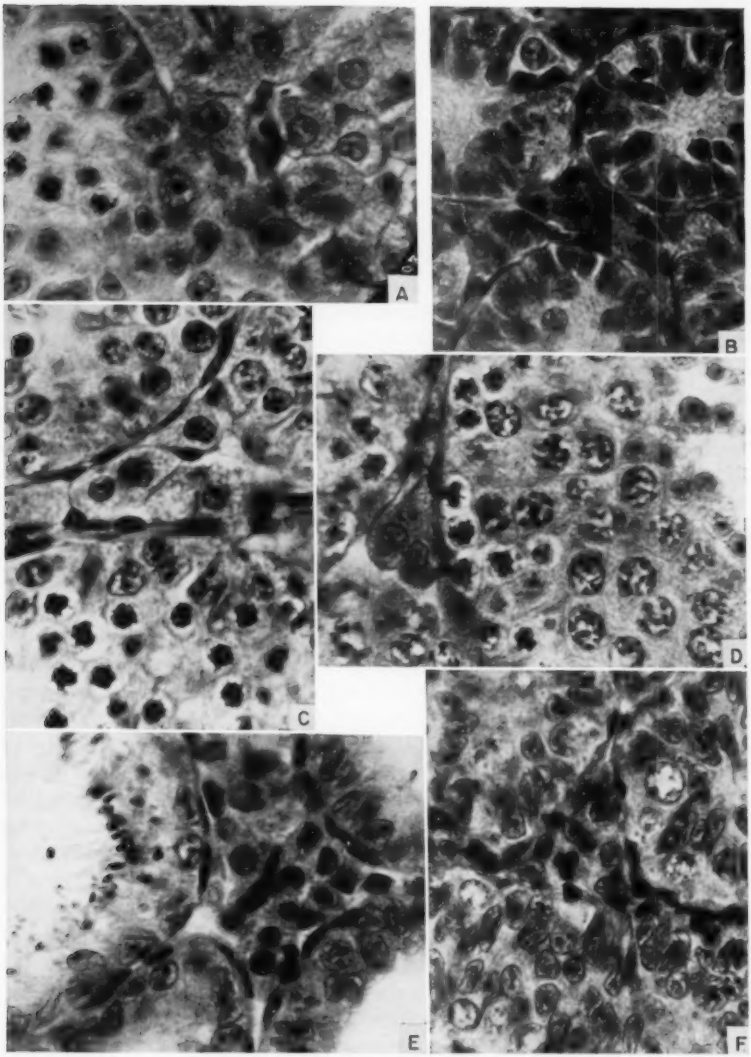

PLATE III

Interstitial cell cycle of the male. All 710×. A: young, about three months, August 26; interstitial cells, right half of picture, larger and volume of tissue greater than at any later time in life of animal; spermatogenesis beginning in few tubules; few cells at synizesis and few spermatogonia and Sertoli cells in seminiferous tubules, left of figure. B: young, December 20; interstitial cells small; seminiferous tubules contain only spermatogonia and Sertoli cells; testis gave negative reaction with 2,4-dinitrophenylhydrazine. C: adult, July 23; testes enlarging and contain great numbers of germ cells at synizesis (lower tubule); sex accessories tiny despite fact that interstitial cells have become much larger than in winter. D: adult, September 2; testis at maximum size, spermatogenesis at peak, size of interstitial cells declining, sex accessories still small; synizesis, primary spermatocytes, and spermatids in tubule at right. E: adult, October 5; shrinking interstitial cells associated with large sex accessories; spermatogenesis completed; tubules contained only Sertoli cells, spermatogonia, and spermatozoa. F: adult, December 20; small, 2,4-dinitrophenylhydrazine-negative interstitial cells of winter testis associated with large sex accessories; seminiferous tubules contain Sertoli cells and spermatogonia.

largely to changes in the size of the seminiferous tubules, it is difficult to estimate the total amount of interstitial tissue present at different seasons. It seemed possible that the total volume of interstitial tissue present might be no greater in summer when the cells are large than in winter when they are small but when they might be more numerous. Accordingly, estimates were made of the relative volume of interstitial tissue in a number of specimens. Counts were made of the number of interstitial cells in many random fields of 6-micra sections. The average number of cells per field was then multiplied by the weight of the testis to give a figure proportional to the number of interstitial cells per testis. The average radius of the interstitial cells was determined and this measurement cubed to give a figure proportional to the volume of the average cell. Multiplying this relative volume by the relative number of cells per testis gives the relative volume of interstitial tissue in the testes of the various specimens. The results of the calculations are plotted in Figure 2. It will be seen that the curve for volume of interstitial tissue follows closely that for diameter of the interstitial cells, that it runs inversely to the curve for size of the ampullary glands, and that the biggest interstitial cells and the greatest volume of interstitial tissue were found in immature males possessing small sex accessories or in infertile summer adults with small accessories.

The apparent paradox of libido and fully-developed sex accessories associated with atrophied testes and shriveled interstitial cells throughout the winter was investigated further in the following fashion: six adult males were taken from a wintering tunnel on November 11 and were thereafter kept in a dark room at about 68° F., and fed daily. Three of them were castrated on November 11 without disturbing the epididymides. The testes were 4.5 to 6 mm. long. One castrate and one control were killed on November 26, and the remaining four on November 28. In each case the ampullary glands and prostates of the castrates were considerably smaller than those of the controls. This suggests that the testes at this time, despite their shrunken size and the inactive appearance of their interstitial cells (Plate III, F), actually are producing androgens. Abundant, vigorous spermatozoa remained in the epididymides of both castrate and control animals.

In an attempt to demonstrate further that the regressed interstitial cells of hibernating males are endocrinologically active, a histochemical test that has been used to show the presence of androgens and other ketosteroids was applied to the testes of two adult males and a young male killed on September 17, and to two adults and a young male taken from hibernation and killed on December 20. The sex accessories of the September adults were enlarging and those of the December adults were of full size. The accessories of both young were tiny. After fixation for 20 hours in 10 per cent formalin, frozen sections of the testes were treated with 2,4-dinitrophenylhydrazine according to the method of Albert and Leblond (1946). Testes of three house mice were fixed and prepared in the same solutions at the same time to serve as checks on the proper functioning of the histochemical test. Two of the mice were adults with fully-developed seminal vesicles, the other a smaller mouse with small seminal vesicles. The mice with large vesicles gave strong positive reactions with 2,4-dinitrophenylhydrazine,

the mouse with small vesicles gave no reaction, and none of the bats gave any reaction either of interstitial or tubular elements. This situation combining poor interstitial cell development and negative histochemical reactions with apparent androgen activity of the testis is puzzling, but it is not restricted to bats, for it has been encountered in some reptiles (Pearson and Fox, unpublished).

In summary, it must be concluded that the endocrine relationship between testis, sex accessories, and sex behavior in *Corynorhinus* is not the same as has been postulated for other mammals. Further work on bats is desirable in which actual hormone production is known and in which the period of responsiveness of the target organs is known. *Corynorhinus* and other species of bats (see Courrier, 1927), because of the unusually clear cycle of the interstitial cells, would be interesting subjects for any such work that involved a study of the cytology of the interstitial cells.

Copulation.—Copulation among *Corynorhinus* occurs for the most part in the winter roosts, but some, perhaps most, females have mated at least once before they arrive at the wintering places. Females captured throughout September have not been inseminated, but in every female examined after October 21 spermatozoa were found. In other words, every female whether young or adult was inseminated at some time during the first three weeks of October. The earliest records of mated females are those of an adult and a young one from Shasta County on October 5. The adult, as well as an adult male with sperm in the epididymis, was taken in a small tunnel that was not used as a winter roost. The young female was the only bat in the Subway Cave winter roost at the time and the rest of this colony did not appear in numbers until more than two weeks later. Two other females captured nearby in houses on October 5 had not yet mated. The fact that these earliest two records of copulation appeared among the few specimens that we have taken in October in the Mt. Lassen region suggests strongly that in cold climates copulation occurs earlier than it does further south at lower altitudes.

The distribution of points in Figure 3 indicates that young females only 4 months old mate as early as do adults—a finding not surprising in the light of the peculiar copulatory behavior described below. Young males, as pointed out earlier, probably do not copulate in their first year.

In any group of females taken at a winter roost, a large drop of semen can be expressed from the vagina of some but not of others, although vaginal smears or sections show that all the females have been inseminated. In view of the activity that we have observed in winter colonies, and the probability that the vagina is emptied in an active female, we feel confident that the presence of a considerable amount of semen in the vagina indicates a recent copulation. Frequently such specimens also have wet, mussed fur on the back of the neck, and the fur in the vulvar region may be smeared with sperm. Judging by the frequency of occurrence of specimens giving evidence of a recent copulation, the peak of copulatory activity comes in the winter roost from November to February. Drops of semen could be expressed from the vagina of many females as late as February 26.

Pre-copulatory behavior in captivity was noted on March 20 after four males

taken from hibernation on March 11 had been confined for nine days with an unmated female (isolated since the previous September) in a cage measuring 16 x 26 x 40 inches. While she hung by her hind feet from the wire top of the cage, one of the males would approach her from the front while making a twittering sound and would embrace her with his wings. Then would follow a long period, sometimes more than a minute, during which he vigorously rubbed his snout over the face, neck, forearms, and ventral surface of the female. During these periods of nuzzling we received the distinct impression that he was making use of his nose glands, which are greatly enlarged in *Corynorhinus*, for inducing submission of the female. We noted on several occasions a strong bat odor in the room. Occasionally the male started to make his way around onto the back of the

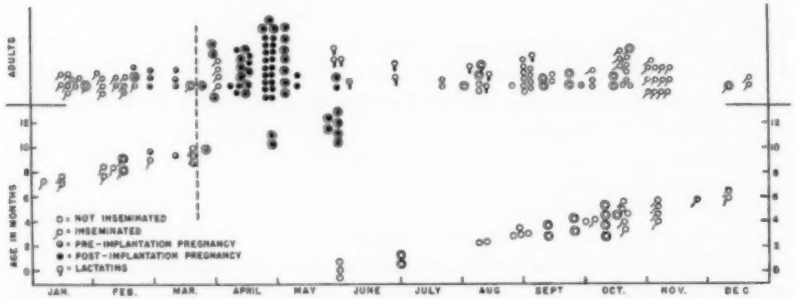

FIG. 3.—The reproductive cycle of young and adult female *Corynorhinus* throughout the year. From birth until the middle of March, when the blastocysts implant, the young can be recognized by their tiny nipples and immature uteri, but after this time (indicated by vertical line at March 20) all specimens were recorded as adults unless they had been banded and consequently were known to be yearlings. Symbols surrounded by rings represent specimens banded at a time such that upon dissection they were known to be either young (less than one year old) or adult (more than one year old). Each symbol represents a dissected specimen. Hundreds of other pregnant, lactating, and immature females were banded and released; these are not represented on the chart. Barren and resorbing females also are not shown.

female, but more often than not he remained at the front and continued the nosing performance. On one occasion he mounted on the female's back, whereupon she started to crawl slowly across the top of the cage, the male moved along with her and kept her well covered. No intromission occurred. Several times the female flew off and landed a few feet away. The male then seemed not to know where she was and would set off in search. He would embrace and nose the first bat that he encountered regardless of sex. Even torpid males would receive from him as much as a minute of nosing before he continued his search.

Only one copulation was seen, and this occurred on such a high ceiling in Subway Cave that it was not possible to learn how the male circumvents the female's interfemoral membrane, which during torpidity is usually tightly curled over the abdomen. The female in the case observed was torpid and hanging by herself from the open ceiling at 6:00 P.M. on November 6; at 8:30 P.M. she was at the

same spot, but a male embraced her from behind in the usual manner of copulating mammals. This pair was captured in a net. The male had an enlarged penis, the skin of which was brighter pink than that of other males nearby. A large drop of semen could be expressed from the vagina by slight pressure on the belly of the female. Although the male was awake and attempted to escape, the female was completely torpid.

On the evening of December 19, 1949, in the Manhattan Mines winter roost, we encircled with chalk a torpid female that was hanging alone from the ceiling. In the morning she was torpid at the same spot with a torpid male on her back. Semen could also be expressed from her vagina. On the basis of such evidence it seems likely that at times the males approach and achieve intromission while the females are torpid.

With the females unable to escape it is perhaps only of academic interest to investigate whether they are actually receptive, or estrous. Vaginal smears made during the period of copulation (October until February, at least) contain, in addition to spermatozoa, large numbers of nucleated epithelial cells, no leucocytes, and very few cornified cells—a smear that would be considered proestrous in mice or rats. The ovaries at this time usually contain one medium-sized follicle (the one destined to ovulate many months later) that in degree of development seems more like a proestrous than estrous follicle. In a few cases females with no large or medium-sized follicles had been inseminated. At ovulation, a time that might be considered homologous to estrus in more conventional mammals, the vaginal smear still contains predominantly nucleated epithelial cells, spermatozoa, and only a few cornified cells. Sections of the vagina in fall, winter, and spring show a deeply stratified epithelium, but no true cornification. It is concluded that at no time does the vaginal epithelium reach the condition typical of estrus in many rodents.

It seems likely that the passivity of the females and the absence of a vaginal plug would permit each female to be mated many times in the course of the winter. The fact that all females in the hibernation tunnels contain sperm in early November, yet copulations are still occurring in the middle of winter, suggests that the males are mating with females already inseminated, and in one individual we know that this occurred. This female had sperm in the vagina on November 11 and on the following January 3 gave evidence of a fresh copulation.

Copulations probably continue until at least February 26, for we have encountered females on this date with wet, mussed fur on the back of the neck and large drops of semen readily expressible from the vagina. Also, females with cleaving ova in the uterus and with abundant spermatozoa in the vagina have been taken as late as March 11, which suggests that additional copulations may take place near the time of ovulation. The males carry sperm and possess large sex accessories until early April.

No firm vaginal plug is formed following copulation. The large white drop of semen expressible from the vagina is occasionally mucilaginous enough to be picked up with forceps and when placed in Bouin's fluid becomes firm enough to be handled and embedded in paraffin for sectioning.

The Female

Anatomy of the female.—The reproductive organs of female *Corynorhinus* are similar to those of *Myotis* (Guthrie, 1933*b*; Wimsatt, 1944*b*). The two uterine horns join at the corpus uteri in such a manner that there is continuous and uninterrupted passage from the lumen of one uterine horn to that of the other. The vaginal opening between the anus and the urogenital papilla is never closed. The ovaries are relatively large and well encapsulated. The round ligament is pigmented as in *Myotis sodalis*, whereas no pigment is present in *M. lucifugus* (Guthrie, 1933*b*). Large follicles and corpora lutea do not project from the surface of the ovary and are not highly colored; consequently they are frequently invisible even under a dissecting microscope.

Determining the age of females.—In the absence of satisfactory skeletal and dental changes the most reliable criteria for determining the age of female *Corynorhinus* are condition of the uteri and nipples. These are not entirely satisfactory in that actually they distinguish parous from non-parous females rather than young from old. Thus, an adult that had never bred would probably be classified as a young female. Since barren females are rare (see below) we estimate that at least 90 per cent of the females taken from summer to early spring can be correctly sorted into the young or adult categories by examination of the nipples alone.

In parous, and consequently adult, individuals the right horn of the uterus, which lies transversely in the body cavity, tends to be broader in an antero-posterior direction than in young females. It is usually almost two mm. broad in non-pregnant adults and only one mm. broad in young. Furthermore, the uterine artery winding along the anterior border of the right horn of the uterus is tortuous and is surrounded by a conspicuous white sheath in parous females, but is relatively straight and thin-walled in immatures. This feature may be seen readily under a dissecting microscope. Care should be taken not to manipulate the uterus more than necessary before examining it, for pinching or prodding will blanch the tissues and reduce the color contrast between the arterial sheath and the underlying uterus. In sectioned uteri, also the arterial walls of parous females are seen to be thickened by fibrous connective tissue.

The nipples of immature females remain tiny until near the time of implantation of the embryo during the first pregnancy (see below) and so may be used for age diagnosis until the young females are about nine months old. This is also the time when the uterus ceases to be useful as an age indicator.

The age of specimens recorded in Figure 3, which summarizes the reproductive condition of females throughout the year, was usually determined by these criteria unless the specimen had been banded.

Growth of the follicle.—The life history of ovarian follicles is especially interesting in bats becauses of the unusual longevity of the follicles destined to ovulate. Such follicles are well developed in October, as much as six months before the time of ovulation.

Ovarian follicles in immature and lactating females during the summer are seldom over 250 micra in diameter, contain small, dark-staining, granulosa cells,

and usually have only a small antrum. Late in September, and in October before copulation, the larger follicles in each female expand to between 250 and 340 micra, but retain small granulosa and cumulus cells. In any one individual there may be several follicles of about this size and no one of them can be recognized yet as the one destined to dominate the ovary during the fall and winter, and to rupture in the spring. The largest pre-copulatory follicle of some specimens may be larger than the dominant post-copulatory follicle of others.

In almost all females that have copulated, the single follicle that will rupture in the spring is recognized easily because it is larger (usually between 300 and 400 micra in diameter) than the remaining follicles and because the cumulus oophorus becomes organized into a large, distinct ball that surrounds the ovum and fills most of the follicle. The cytoplasm of the cumulus cells increases, and the consequent wider spacing of the nuclei gives the entire follicle a characteristic pale appearance that is easily recognized in stained sections (Pl. IV, C). Never was one of these pale follicles with a fully-developed ball of cumulus cells found in a female that had not copulated. Five females that were captured on September 16 before they had copulated were caged and fed in isolation from males, then were put into hibernation at 42° F. on November 15, still isolated from males. One, killed on December 11, had a large follicle, but the cumulus cells were not fully developed. The other four were removed from hibernation on March 4, 12, 18, and 19, respectively. They were then kept at room temperature and fed for nine to 12 days, then sacrificed. One of the four contained a medium-sized follicle of the pre-copulatory kind. The other three contained no large or medium follicles or corpora lutea. That conditions of captivity caused disappearance of large, post-copulation-type follicles in these females is not probable since females captured after copulation and kept over winter had normal post-copulatory follicles when killed in the spring. In view of these findings it seems possible that maturation of the follicle and its subsequent ovulation in *Corynorhinus* may depend upon the stimulation of copulation, and that this stimulus may be effective even though administered several months before ovulation. It has been claimed that spontaneous ovulation occurs in other vespertilionid bats, but evidence from females denied copulation has not been presented.

In three cases females collected in midwinter had no large dominant follicle in the ovaries. One of these specimens was taken in January and two in February; all three were young females and in each case they had copulated (spermatozoa in the uterus). It is quite possible that these three would have failed to ovulate in the spring.

The dominant follicle grows little if any during much of the winter. Among females wintering in the Subway, Parrish, and Lava Bed caves, follicles averaged about as large in early November as in January. Definite growth had occurred, however, before early April. Among specimens taken in autumn and winter from all regions, follicles were as large in young females as in adults. The largest follicle encountered, one about to rupture judging by the fact that the ovum had formed the first maturation spindle, was 490 micra.

The ripe follicles of *Corynorhinus* differ from those of other mammals (except

shrews and other bats) in the relative smallness of the antrum and in the presence of the enormous ball of cumulus cells surrounding the ovum, mentioned above. Formation of such follicles might be achieved if the granulosa and cumulus cells of shrews and bats merely retained their "secretions" instead of releasing them into the follicular fluid of the antrum.

The ova in the largest follicles of summer specimens are already of full size and grow no further during the pre-copulatory and pre-ovulatory growth of the follicle. In fact, there is some evidence that they shrink slightly as ovulation approaches. The diameter, measured inside the zona pellucida, of the ovum from the largest follicle in sections of 54 non-pregnant females from June to April averaged 83.4 micra with a range from 68 to 98 micra.

Ovulation and early development.—The two ovaries are about equally active, for, of 34 pairs of ovaries containing corpora lutea, ovulation had occurred in the left ovary 19 times and 15 times in the right. There was no tendency for young females to have their first ovulation only in the right or only in the left ovary.

The process of ovulation in *Corynorhinus* is similar to that in the shrew (Pearson, 1944) and in the bat *Myotis lucifugus*, a species in which ovulation has been splendidly illustrated by Wimsatt (1944*a*). When the follicle of *Corynorhinus* ruptures, the ovum and its entire surrounding ball of cells is ejected and enters the oviduct. The cells surrounding the ovum are shed in the early part of the passage of the ovum down the oviduct. At the moment of ovulation the first polar body and second meiotic spindle have been formed and, as in most mammals, the ovum is still at this stage when it enters the oviduct and becomes fertilized. Fertilization (semination) occurs in the upper half of the oviduct and the first cleavages occur in the middle portion of the oviduct. The segmenting ovum enters the uterus when there are between six and eleven blastomeres. The length of time required for the ovum to pass through the oviduct is not known, and is probably quite variable depending upon environmental temperature. A suggestion of the relative length of time spent at different stages can be obtained from the number of specimens caught at different stages. Of eleven specimens with ova in the periovarial capsule or in the oviduct, three had second meiotic spindles, four had pronuclei, and cleavage had begun in four.

Among seven sectioned specimens that contained blastocysts or segmenting ova in the uterus, the number of embryonic cells ranged from 11 to about 80. A zona pellucida was visible around some of these ova, but not around others. The smallest of the dividing ova in the oviduct and uterus was an eleven-celled blastula that was 53 micra in diameter, exclusive of the zona pellucida, and the largest was a blastocyst of about 75 cells that was 78 micra in diameter. The average diameter of five uncleaved tubal ova was 73 micra, so it is apparent that growth does not occur until after the eighty-celled stage has been reached. Large vacuoles appear in the cytoplasm of the cleaving ova, and these presumably enlarge and fuse to form the blastocyst cavity as Wimsatt (1944*b*) has described for *Myotis*.

The time of ovulation.—The earliest ovulations among our specimens occurred at the Inverness colony. Of three females taken there on February 20, 1950, one

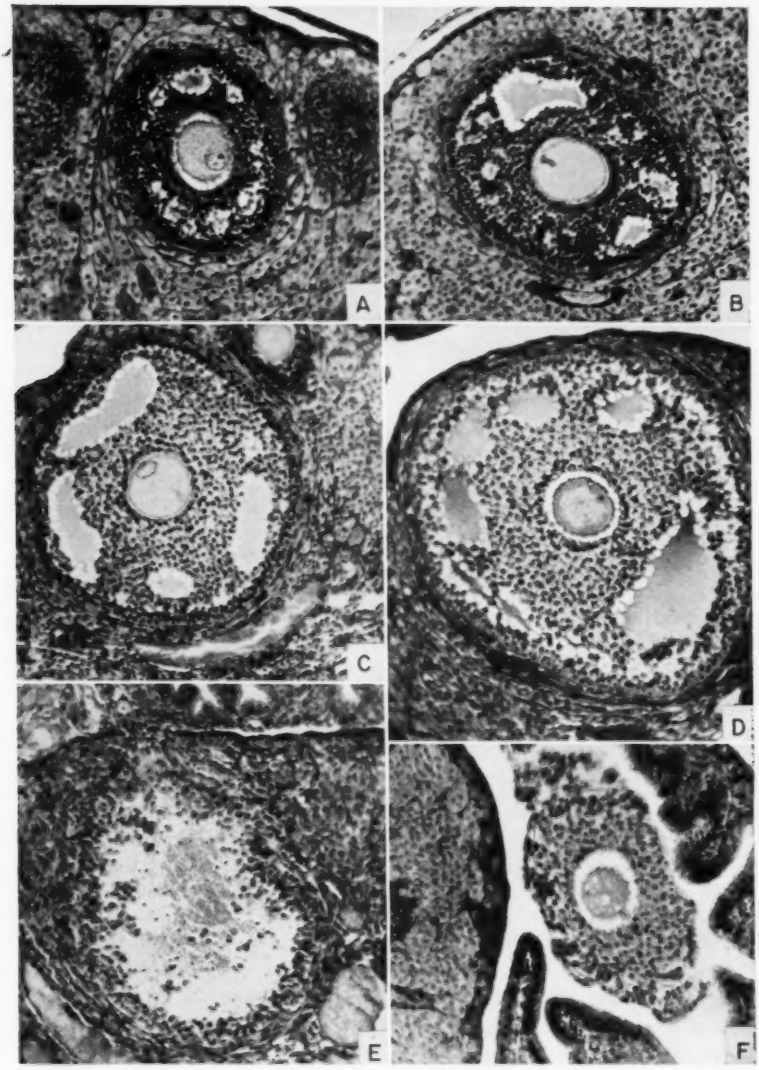

PLATE IV

Life history of the follicle. All 120×. A: largest follicle in ovary, lactating female, August 10; many such follicles become atretic, presumably this one would not have ovulated. B: largest follicle in ovary of adult female, October 16, before copulation; this follicle possibly destined to develop into dominant winter follicle and ovulate in the spring; some pre-copulation growth, but cumulus cells surrounding ovum still small, resulting in close-packed nuclei. C: largest follicle of young, mated female, taken from hibernation, November 6; cumulus cells have enlarged, spreading nuclei further apart; follicles remain in this condition throughout winter. D: follicle after pre-ovulatory growth, about to rupture; first maturation spindle has formed; April 3. E: recently ruptured follicle, March 19; a fertilized ovum containing two pronuclei was found in the oviduct; point of rupture is at top of photo; mass of blood corpuscles visible in follicle. F; ovum surrounded by large mass of cumulus cells, entering oviduct; polar body and metaphase of second meiotic division have formed.

had an ovum just entering the oviduct, another had an ovum in the oviduct, and the third contained a follicle about to rupture. Five females taken at other roosts in central California on February 17, 1950, had not yet ovulated. The latest ovulations of central California specimens were noted in two females taken at the Inverness colony on March 31, 1949. One contained a fertilized ovum with polar bodies but no pronuclei, and in the other was found a tubal ovum of four cells. Four specimens taken in northern California (Shasta County) on April 3 had not yet ovulated. Three of these were still in their wintering cave and gave no evidence of imminent ovulation, and the fourth, which was in a small tunnel not used for wintering, possessed a follicle so near rupture that the first maturation spindle had formed. Our records do not demonstrate any difference in the time of ovulation of young and adults. More nearly complete records on dates of parturition show that on the average adult females give birth earlier than do young females, but this does not necessarily prove earlier ovulation in adults because the duration of pregnancy is so variable.

The place of ovulation.—It is probable that the *Corynorhinus* in cold regions ovulate, as do eastern *Myotis* (Wimsatt, 1944*a*), a few days after leaving the winter tunnels. In central California, however, we have found recently-ovulated females in winter tunnels, in nursery colonies, and in other roosts; and conversely, in all three situations we have found, at the same time of year, females that have not yet ovulated. This fact, plus the facts that the nursery colonies do not reach full size until late April or May, and that we have found females in early pregnancy roosting in places not used by a nursery colony, leads us to conclude that the females do not join the colonies as soon as they become reproductively active in the spring. Apparently, during early pregnancy the tendency for the bats to organize into colonies is not as great as it is either during the winter or later in the spring. We have found no late pregnant females roosting alone away from a nursery colony, neither have we found females with nursing young in such places.

Ovulation in captivity.—Numerous workers agree that hibernating bats will ovulate when brought into warm rooms, and that bats collected late in the winter ovulate more readily than those brought in earlier. Guthrie and Jeffers (1938), for example, reported that in *Myotis lucifugus* brought into the laboratory between early February and mid-March ovulation occurred in scattered individuals after one to two weeks at the higher temperatures, and that after mid-March increasing numbers of individuals ovulated within a few days after collection. Wimsatt (1944*a*) found that *Myotis lucifugus* removed from caves on April 25 near the end of hibernation ovulated within four days. Several papers also report that induction of ovulation by injections of gonadotropic hormones is more successful in late than in early winter.

Two *Corynorhinus* removed from a hibernation tunnel in Shasta County on November 9, and kept in a cold room at 45° F., contained no corpora lutea on January 18 and 25, respectively. Another removed from hibernation in Siskiyou County on February 5, and kept at 45° F. until April 6, had not ovulated. In Table 1 will be found records of other females removed from hibernation tunnels

in Shasta or Siskiyou County and kept for various lengths of time at 65° to 75°F. The first two listed were actually captured November 9, but were subsequently kept at 45° until December 29. All were fed daily while in the warm room. The pregnancy urine used was from a third-month human pregnancy. The urine was washed with ether and 0.1 cc. was injected into the bats subcutaneously twice daily. The Antuitrin S was a water solution injected subcutaneously. In the first animal five i.u. were injected, and in the second animal, 25 i.u. on each of two days.

From inspection of Table 1 it is concluded that ovulation is not readily induced by removing *Corynorhinus* from hibernation to warm rooms before mid-February, but that injections of pregnancy urine bring about ovulation at this time.

TABLE 1.—*Records of bats removed from hibernation and kept at 65–75° F. All were from Shasta or Siskiyou counties, where ovulation occurs normally in April*

DATE PUT INTO WARM ROOM	DATE KILLED	DAYS IN WARM ROOM	TREATMENT	CONDITION
Dec. 29	Jan. 18	20	None	Not ovulated
Dec. 29	Jan. 24	26	None	Not ovulated
Jan. 15	Mar. 24	68	None	Ovulated, no embryo found
Jan. 15	Mar. 24	68	None	Ovulated, no embryo found
Feb. 4	Feb. 12	8	None	Not ovulated
Feb. 4	Feb. 12	8	Pregnancy urine	Fertilized ovum with pronuclei
Feb. 8	Feb. 12	4	None	Not ovulated
Feb. 8	Feb. 12	4	Pregnancy urine	Fertilized ovum with pronuclei
Feb. 5	Feb. 24	19	None	Blastocyst with 50 cells
Feb. 5	Feb. 24	19	Antuitrin S Feb. 18	Not ovulated
Feb. 5	Feb. 27	22	None	Not ovulated
Feb. 5	Feb. 27	22	Antuitrin S Feb. 24 and 25	Not ovulated
Feb. 11	Feb. 21	10	None	Not ovulated
Feb. 5	May 9	93	None	Ovulated, no embryo found

Studies of bats of the eastern United States and of Europe have led to the widely held belief that bats are basically species that would mate and ovulate in the autumn were it not for the fact that the normal sequence of estrus and ovulation is interrupted by a long period of hibernation. This thesis is not supported by our observations on *Corynorhinus* because many females in central California are active during the winter months without ovulating, and because ovulation does not occur readily in females removed from hibernation early in the winter and kept at a warm temperature. It is apparent that there is a refractory period during the autumn and early winter during which ovulation does not normally occur, just as in many other species of spring-breeding animals. This leads us to suspect that *Corynorhinus*, and possibly other vespertilionids, may be basically a spring-ovulating species in which evolution among the males has ad-

vanced the time of copulation—an evolution made possible by long sperm survival in the female and by the fact that unreceptive females can be inseminated while torpid.

The uterus.—At one month of age the right horn of the uterus of some specimens is noticeably longer than the left, and a similar difference in length can be detected in most young females during their first autumn and winter. The diameter of the two horns is about equal in young females, however, and this condition can be used to recognize young or non-parous females (see above). The diameter of the uterine horns of young females before the autumn copulations, as well as during the winter when sperm are being stored, is usually about one mm. At the time of ovulation the two horns are still of the same diameter, but give the impression of being slightly swollen or turgid. The uteri of one such ovulating specimen, however, still measured only 1.2 mm. in diameter whereas in a banded young female with an eighty-celled segmenting ovum in the uterus the right horn had become larger than the left and was 1.8 mm. in diameter.

After parturition the right horn, which in 49 out of 50 observed pregnancies carried the young, never regresses to its original small size, but remains broader than the left. It is usually flattened in a dorso-ventral direction so that its greatest diameter is antero-posterior. In summer, autumn, and winter specimens this antero-posterior diameter of the right horn is usually between 1.5 and 2 mm. The larger size of the right horn over the left probably led Bailey (1936) to the conclusion that specimens collected on October 13 in caves in northern California were pregnant. He stated that they were carrying embryos the size of no. 8 shot. We collected *Corynorhinus* in these same caves in midwinter and found no pregnant females.

The first gross sign of pregnancy in the adult uterus is a slight plumpness of the right or of both horns. This swelling results in an increase in the dorso-ventral diameter of the right horn before the dimensions increase in other directions. Plumpness was already detectable in the uterus of a specimen with an uncleaved tubal ovum, but was not detected in another specimen at this stage, nor in a specimen with a four-celled tubal ovum. The right horn had swollen to an antero-posterior diameter of 3.5 mm. in a specimen containing a twenty-two-celled uterine embryo, but in two more advanced pregnancies, with the embryo already implanted, the diameter was only 2 and 3 mm., respectively. These records indicate that the progestational response of the uterus is so variable that size of the uterus is not reliable as a basis upon which to estimate the stage of development of very young embryos. Vascularity of the uterus increases considerably near the time of implantation.

Careful examination of many histological sections of uteri disclosed no morphological feature of the epithelium or endometrium in the right horn that would induce the ovum to implant almost always here rather than in the left horn.

During pregnancy the right horn enlarges to such an extent that the left is almost totally enveloped. After parturition the right horn regresses to its resting size in from two to three weeks.

Survival of spermatozoa.—It has been shown above that spermatozoa in the

male retain their motility for six or more months after they reach the epididymis. It is not known whether these motile spring spermatozoa are capable of fertilizing, for males removed from hibernation tunnels in March could not be induced to copulate in captivity with unmated females kept isolated for this purpose from the previous September.

In females of some other species of vespertilionid bats, investigators have shown that spermatozoa stored over winter in the female reproductive tract are capable of fertilizing in the spring. In *Corynorhinus*, histological sections from females caught during the winter revealed abundant spermatozoa. These were usually located near the tubo-uterine junction and in the cervix, not in the bladder. Vaginal smears made during the winter usually contained spermatozoa. Spermatozoa were abundant in sections of the uteri of two females kept isolated at 42° F. from mid-December to late March (108 days), and motile spermatozoa were found in females segregated from males and kept at 45° F. from early in November until January (76 days). In specimens removed from hibernation and kept at room temperature, spermatozoa were found in all that had not yet ovulated at the time that they were killed. Some of these had been kept at room temperature for 26 days. Spermatozoa disappear quickly from the female reproductive tract shortly after ovulation.

Duration of pregnancy.—The best measurements of duration of pregnancy can be derived from our observations on the Aetna Springs and Inverness colonies. These observations are summarized in Figure 4. Considering first the Aetna Springs colony, and combining the years 1949 and 1950 because gestation in this colony in these two years was so similar, it will be seen that specimens on March 11 had ovulated and contained tubal or uterine ova. Assuming that five days had elapsed since ovulation and fertilization, and considering fertilization to be the beginning of pregnancy, then gestation in these Aetna Springs bats can be assumed to have begun about March 6. If we assume further that March 6 was the average ovulation date for the colony, then 84 days would have elapsed until the average birth date for that colony, May 29. The manner of calculating the average birth date will be explained below. Since the three specimens taken at Aetna Springs on March 11 were the only bats at the nursery colony and thus may not have been at a stage of pregnancy typical of the whole colony, we have also calculated gestation on the assumption that these three were at the nursery colony before the others because their reproductive condition was more advanced than that of the rest of the colony. The recalculation merely entails figuring gestation from March 6, as before, until the *earliest* birth date instead of the average birth date. The earliest birth occurred on May 18, and this indicates a pregnancy of about 73 days.

Similar calculations for the Inverness colony give an average gestation of 69 or 56 days in 1949. In 1950 at Inverness, calculated gestation was longer, 96 and 80 days, perhaps because of climatic differences in the two years.

Evidence of an even longer gestation was derived from successive visits to the colony occupying the Manhattan Mines. Of four females taken at random on February 27, 1950, two contained unfertilized tubal ova, one a five-celled ovum

in the oviduct, and one a sixteen-celled ovum in the uterus. This suggests an average ovulation date of about February 24. Sixty-two days later, fourteen females taken at random from this colony carried embryos from 2.5 to 14 mm.

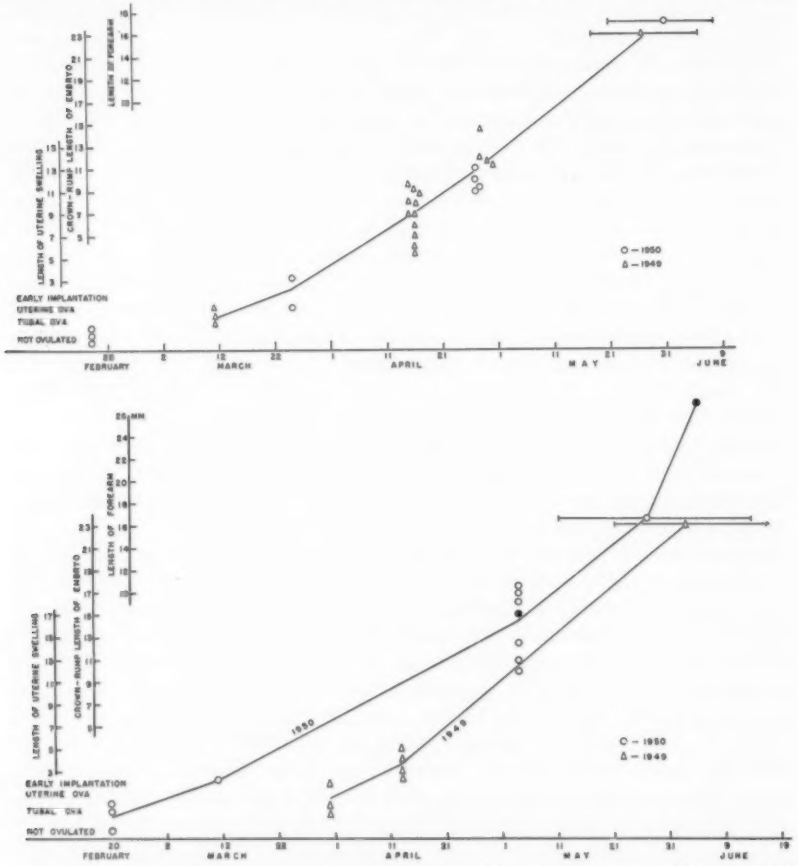

FIG. 4.—Growth of embryos at Aetna Springs (above) and at Inverness (below) in 1949 and 1950. The three scales along the vertical axis may be used to equate the three sets of measurements used for fetal and newly-born bats. The longitudinal lines in the upper right of each figure represent the spread of birth dates in the two years. The growth curves intersect them at the mean birth dates. The two solid circles in the lower figure represent successive measurements on the same individual; once as a fetus while its mother was anesthetized and again as a nursing young when its mother was recaptured.

CR (crown-rump), average 8.8 mm. Judging from the embryo growth-curve of the nearby Aetna Springs colony, an 8.8-mm. embryo is not born for 38 more days, which would give for this colony an average gestation of 100 days.

Comparison of the performance of the Aetna and Inverness colonies indicates that in 1949 gestation was shorter at Inverness than at Aetna Springs, whereas in 1950 it was longer at Inverness. Such variability in the length of gestation is most unusual among mammals and may be associated with varying amounts of torpidity in different years with different climatic conditions. If environmental conditions stimulate ovulation unusually early in the spring, and there follows a protracted cold period during which the bats are torpid most of the time, the early stages of pregnancy may proceed very slowly. This could account for variation in the length of gestation in different years and in different colonies.

Substantial evidence that temperature can influence the length of gestation in bats has been presented by Eisentraut (1937), who found that when *Myotis myotis* were kept in cool rooms their body temperatures were low and embryonic development was slow. Development was speeded when the bats were kept warm.

Morrison (1945) has suggested that the body temperature of the usually poikilothermic sloth is kept at a high level during pregnancy, and there is evidence that the pregnancy hormone, progesterone, exercises such an effect in some animals. However, Eisentraut's evidence and our own temperature measurements on captive, mid-pregnant *Corynorhinus* indicate that daily torpidity *can* occur in bats even during pregnancy. In the wild, however, *Corynorhinus* is seldom found in a cold, torpid condition after the embryos have become implanted. This wakefulness may not result as much from internal temperature control as from the fact that post-implantation pregnant females choose warm places as nursery sites and gather there in large clusters. We conclude that development of the embryos is probably more uniform after implantation, when almost all females have a warm body temperature, than in early pregnancy when some females have low body temperatures and others high.

Further evidence that the duration of pregnancy in *Corynorhinus* is capable of being modified by environmental conditions is afforded by comparison of the breeding behavior in widely different latitudes and altitudes where climate is considerably different. A search of the literature and of specimens in the Museum of Vertebrate Zoology has disclosed no clear tendency for *Corynorhinus* in cold regions to give birth to their young later than in warm regions, yet in cold regions, as in Shasta County, many bats are still hibernating and are sexually inactive a month after some individuals in warmer regions have begun to ovulate. For parturition to occur at the same time in the two regions, gestation would have to be shorter in the bats in the cold climate. This appears to be impossible in the light of the conclusions reached above concerning the effect of temperature on embryonic development, but it is quite possible that once the bats in cold regions have emerged from hibernation in late March or early April they meet, or even seek, temperatures as warm as those encountered by the bats in regions farther south or at a lower elevation.

Parturition.—The most interesting aspect of the birth process is the manner in which the mother eliminates the danger of the young falling to the ground. In a caged specimen at the time of parturition, the mother suspended herself from the wire top of the cage by both hind feet spread widely, and by both thumbs.

The tail and its membrane were curved upward in such a fashion that in conjunction with the wing membranes it formed a spacious basket out of which the young could scarcely fall. The fluids and afterbirth were consumed by the mother; no drop of blood reached the floor of the cage. The mother maintained this position for more than a half hour after parturition. A few minutes after birth, while the mother was licking her young and her own membranes, the young had attached to a nipple and was hanging by its feet from the top of the cage, but still within

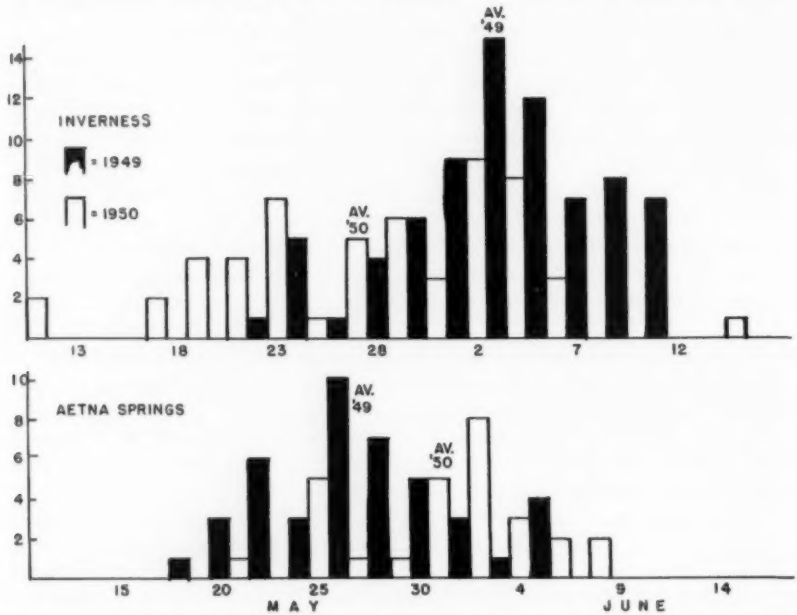

FIG. 5.—Frequency distribution of birth dates at the Inverness and Aetna Springs nursery colonies in 1949 and 1950. Birth dates were calculated from forearm measurements of the young bats by reference to Figure 7. Each column represents a two-day total.

the limits of the mother's membranes. The one parturition seen at the appropriate stage was a breech presentation.

Dates of parturition.—By study of our field notes and of the collections of *Corynorhinus rafinesquei* of several subspecies from western America in the collection of the Museum of Vertebrate Zoology, and by search of the literature, we have estimated the date of birth of several hundred bats over an area from Lower California to eastern Arizona, north to northern Nevada, from sea level to 5800 feet. Birth dates were estimated from embryo size by reference to Figure 4 (upper) and from forearm measurements of young by reference to Figure 7. The earliest calculated birth date was April 19 for a bat from Mission San Jose, 300

feet, Alameda County, California. The latest was on July 22 at a colony at 5800 feet in Navajo County, Arizona.

The dates of parturition in the different colonies were then compared with the maximum, minimum, and mean temperatures of January, February, March, and April at the nearest government weather station. No clear correlation emerged. In fact, *Corynorhinus* in lower California give birth as late as do those in northern Nevada. This is perhaps not unexpected since the temperatures in the buildings and tunnels in which *Corynorhinus* spends most of its time are often quite different from the outdoor temperatures.

The average date of parturition of a colony varies in different years. The average birth date at Aetna Springs in 1950 (May 31) was four days later than in 1949, whereas at Inverness the average birth date in 1950 (May 27) was at least seven days earlier than in 1949 (Fig. 5). At both places it was colder in the spring of 1949.

There seems also to be considerable variation in the spread of birth dates in different colonies. Births at Aetna Springs were confined to a period of 19 days in each of three seasons, but extended over a period of 30–35 days in each of these years at Inverness (and also at another nursery colony at Manhattan Mines only 12 miles from Aetna Springs). It is probable that birth dates extend over a long period in a colony in which different females roosted in different places at different temperatures before they congregated at the nursery colonies.

There is evidence that the young females tend to join the nursery colony later in the spring than do the adults. Furthermore, we have evidence for several seasons that one-year-old females bear their young later in the season than do adults. At the Inverness colony on May 30, 1948, seven of eight one-year-old females were still pregnant, and the eighth had a baby less than three days old with her. Over 60 per cent of the 48 adult females captured on this date had already delivered their young. In 1950 at Inverness we were able to calculate the birth dates of the offspring of seven banded one-year-old females. Only two of these births occurred before the average birth date for the colony, which was on May 27; the average birth date for the young of the one-year-old females was May 31.

Life history of the corpus luteum.—A single corpus luteum was found in all but one female, a recently pregnant bat taken May 31 that had two corpora lutea of different ages in her right ovary.

At ovulation the ball of cells surrounding the ovum is expelled with the ovum, leaving a somewhat collapsed, hollow corpus luteum. Granulosa cells invade the fluid-filled antrum with the result that the corups luteum becomes solid while the segmenting ovum is free in the uterus. At the same time, the corpus luteum is increasing in size and reaches its maximum diameter, about 725 micra, shortly after the blastocyst has attached and the uterus has become conspicuously swollen. During the early stages of implantation the cytoplasm of the luteal cells becomes foamy and the corpus has the general aspect of corpora in many other mammals. Scarcely has implantation become established than large vacuoles appear in the corpus and these become increasingly abundant as pregnancy

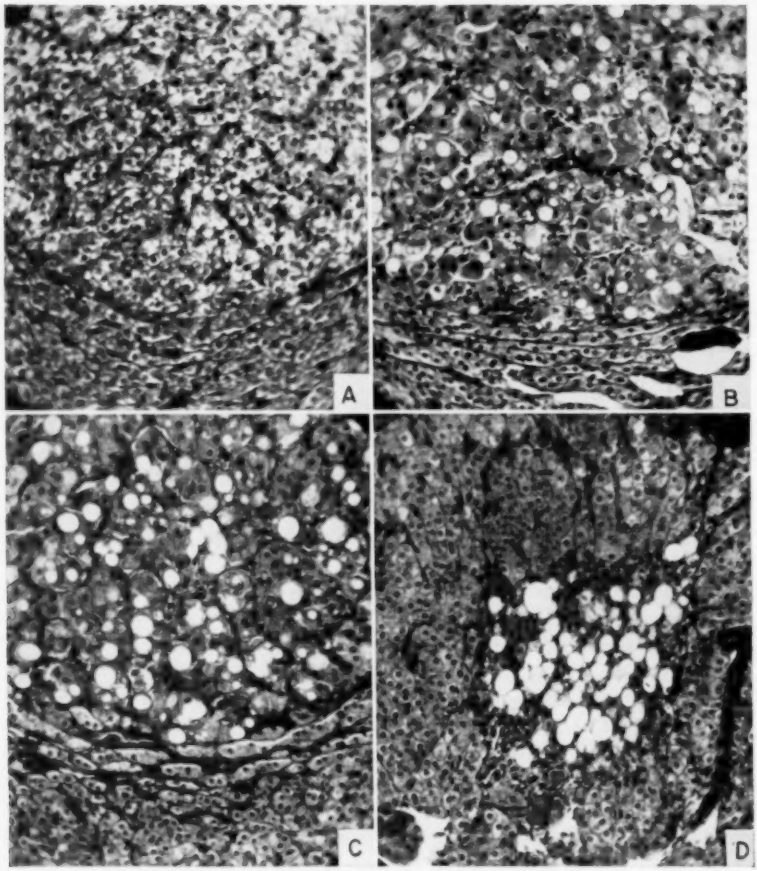

PLATE V

Life history of the corpus luteum. All 120×. A: corpus luteum at time of implantation; corpus has not reached full size; cytoplasm foamy and with small vacuoles. B: corpus luteum at maximum size in a female carrying a 12-mm. CR fetus; large vacuoles have developed. C: corpus luteum of a female one day after parturition; note increased vacuolization. D: remains of corpus luteum of lactating female one month after parturition; note great development of ovarian interstitial tissue.

proceeds. The presence of these vacuoles (Pl. V) gives the corpus a degenerate appearance relatively early in pregnancy. The corpus decreases in size near the end of pregnancy and during lactation. It was only 255 micra in diameter and full of large vacuoles in two females that had been lactating for one month, and the corpus luteum had disappeared completely in three other lactating females.

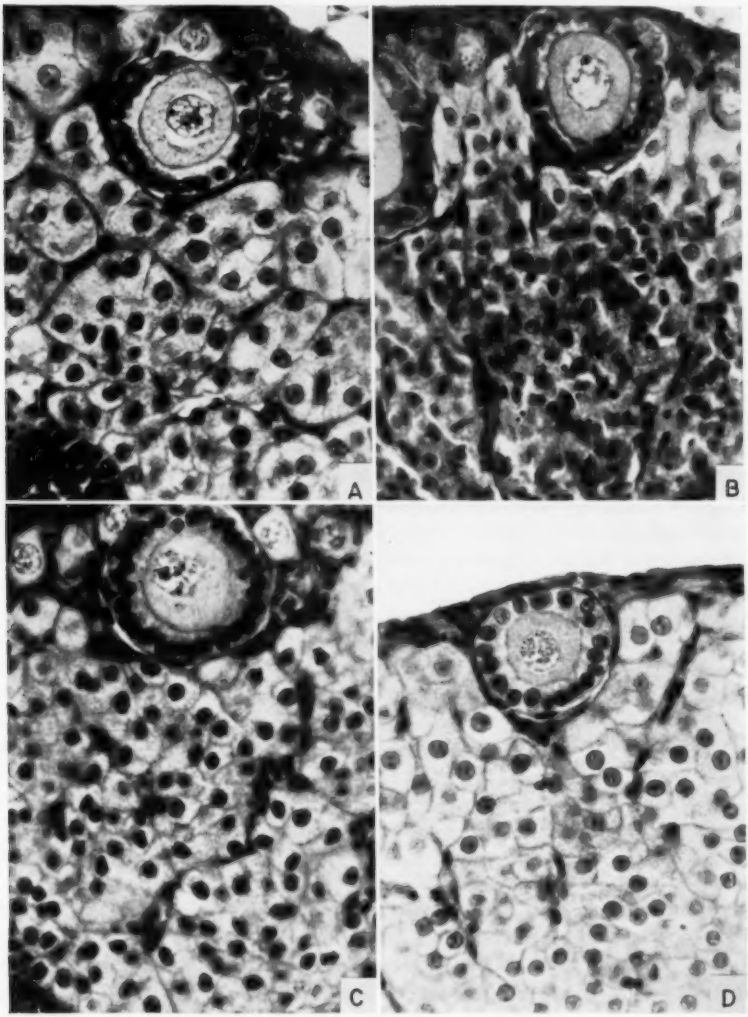

PLATE VI

Interstitial tissue of females. All 380×. A: interstitial cells of a young female in August, about two months old; interstitial tissue is well developed at this time. B: mated adult in hibernation on January 16; interstitial cells of young and adults are relatively poorly developed during the autumn and winter from the time of copulation to ovulation. C: year-old female carrying 13-mm. CR fetus, May 30; interstitial cells better developed than in winter, but many of the nuclei shrunken. D: lactating female one month post-partum; interstitial tissue at maximum development.

At no time does the corpus luteum, or the follicle from which it is derived, protrude conspicuously from the surface of the ovary. Indeed, only occasionally was the corpus located in a fresh ovary with the aid of a dissecting microscope, and even in sectioned material it is never a conspicuous feature of the ovary. From its atrophic appearance during much of pregnancy and all of lactation it seems probable that it has no important secretory function after the embryo has become well implanted.

Interstitial tissue of the ovary.—The ovarian interstitial tissue is almost as remarkable as that of the testis (Pl. VI), and follows a similar though less distinct cycle. Interstitial cells of young females are large and plump but become less so as the breeding season approaches in October. A similar decrease occurs in the size of the interstitial cells of the adults following lactation. The cells remain small in both young and adults throughout the autumn and winter, and enlargement resumes in many individuals during pregnancy. There is considerable variation, however, between different females at the same stage of pregnancy, which leads us to suspect that the interstitial tissue does not play a vital role at this time. During lactation the interstitial cells are most highly developed (Pl. VI, D). A quick glance at sections of the interstitial tissue at this time reminds one of the fully-developed corpus luteum in some other species. The function of this apparently secretory tissue, well endowed with capillaries, is unknown.

Reproductive failure.—Upon examination of adult female bats in nursery colonies from late April, when the females are mid-pregnant, until early June, when they are late pregnant or lactating, it is possible to estimate the frequency of reproductive failure. We have done this for five nursery colonies, two of them for two seasons each. Four hundred and seventy females were examined in these colonies and 26 of them (5.5 per cent) were diagnosed as neither pregnant nor lactating. This per cent must be considered a minimum value for reproductive failure because some of those pregnant at the time of examination may have resorbed or aborted their embryos later. An additional source of error is the probability that many non-pregnant females leave or do not even join the nursery colonies and thus would not be included in the above figures. That this occurs is indicated by the fact that several such females were found in May and June hanging alone in places not used by nursery colonies.

Of the 26 non-productive females recorded, nine were one-year-olds, six were adults (four two-year-olds; one three-year-old; and one four or more years old), and eleven were of unknown age because they were not banded. The nine bats that failed to reproduce at one year of age make up 26 per cent of the 34 banded young females whose reproductive behavior is known beyond question, so it is apparent that reproductive failure is more common in young females than in adults. One chronic non-breeder was noted among our banded bats. This female was banded as an immature in 1947, and, although she was captured in 1948, 1949, and 1950, gave no evidence of having borne a young.

Of 16 non-productive females dissected, two were resorbing their embryos and at least four others had either resorbed or had lost their young shortly after birth (as indicated by a collapsed uterus but no indication of lactation). Numerous

others had ovulated, but at the time of dissection gave no indication of having been pregnant. Twelve of the 16 non-productive females are known to have ovulated, and of the remaining four, the ovaries of three were not sectioned. The fourth, a non-parous female taken on April 27 in a nursery colony and containing no corpus luteum or mature follicles, was the only female known to have missed ovulation. It is clear from this that failure to ovulate is not an important cause of reproductive failure in *Corynorhinus*.

Changes in the pelvis.—The pubic symphysis of the female of many species of mammals separates at the time that she gives birth, and one would expect a similar modification of the pelvis of *Corynorhinus* to facilitate birth of the relatively enormous full-term fetus. In a one-month-old female the ends of the pubic bones were swollen, somewhat knobbed, and clearly approximated although not actually in contact. In lateral view the cleaned bones of the pubic region appeared smooth and rounded. In young females during August and September the pubis of each innominate bone in side view had become slightly drawn out in a ventro-posterior direction so that it appeared to have a square keel. The ends of the pubes were still knobbed, but were not as close together as earlier. Conditions had not changed in a young female carrying a uterine blastocyst in the spring, but in an adult female with a uterine blastocyst the ends of the pubes were thin and flat rather than knobbed. During pregnancy the pubes become flattened further and begin to flare outwards. In specimens one and three days after parturition these changes are pronounced (Fig. 6); there is also an increase in the size of the keel. During lactation the keel becomes reduced and there is some thickening of the pubes, but the ends do not become as knobbed as in young females. It is concluded that in *Corynorhinus* there is some resorption of bone in the pubic region during pregnancy, as well as a thinning and an attenuation of the pubic bones to form a keel, but at no time in the female is there a bony symphysis pubis to be "relaxed," as in some other mammals.

In male *Corynorhinus* the pubic bones are knobbed and unkeeled as in very young females. Sometimes in males the two bones are actually in contact.

Lactation.—In *Corynorhinus* there is a single pair of pectoral mammae in a quite lateral position. Early in the study a subjective classification of nipple sizes was set up, consisting of the following categories: tiny, small, medium, and large. It is difficult to measure accurately the smaller nipples, but in general tiny nipples were those less than 0.6 mm. long in fresh specimens, and the other size-categories ranged larger than this up to about 3 mm. for a large nipple. By making use of banded specimens of known reproductive history it became apparent that tiny nipples were characteristic of young and non-parous females, and that once a female had born young the nipples did not return again to the tiny category, although they frequently became small again.

The nipples of the young remain tiny through the summer, fall, and winter of their first year, and begin to enlarge at about the time of implantation of the embryo. Several young females with fertilized ova or blastocysts still had tiny nipples, but no specimen more advanced in pregnancy than this had tiny nipples. The skin surrounding the tiny nipples of young females, as revealed by blowing

the fur aside, is frequently rosy or purple whereas in adults it is usually pale. This difference is sometimes useful when deciding whether to put a specimen into the tiny (young) or small (adult) category.

Nipples reach full size at the end of pregnancy or shortly thereafter. Mammary tissue first becomes apparent when the fetus is about 7 mm. CR. The mammary tissue on one side of a female 30 hours after she had given birth measured 8 by 15 mm. and was 1.5 mm. thick. In a female nursing a young one month old, the mammary tissue on one side measured 17 by 12 mm., and reached anteriorly under the wing root and around dorsally onto the scapular region.

It is difficult to tell when lactation ceases, for this is gradual, and, furthermore, even in autumn after mammary tissue has all but disappeared a small drop of fluid can frequently be squeezed from each nipple. From the distribution of lactating females in Figure 3, and from observations made in numerous nursery colonies, it appears that mothers nurse their young for about two months. The stomach of one banded young bat 42 days old was full of milk and held no insect remains. This young bat, as large as its mother, was a skillful flyer.

FIG. 6.—Lateral and posterior views of the pelvis of a young, nulliparous female (left) and of a female one day after parturition (right).

One of the most interesting aspects of lactation in *Corynorhinus* is the inclination of the mothers to nurse only their own young, and their ability to select their own young from a large group. When the mothers leave the roost at night to feed, the young are left behind clinging together in one or two large clusters, but during the day each young clings to its mother. Comparison of band numbers of mothers and their accompanying young on successive visits to the same nursery colony showed that in every case the mother was carrying the same young as on the previous visit, hence, whenever she had returned from feeding she must have selected from the cluster of young the same individual that she had left there.

Our best observations of the way in which this is accomplished were made on June 5, 1949, in the Aetna Springs colony. After we had collected, read band numbers, and released the adult females in the rear of the tunnel in which we had found the nursery colony, we released the young on the floor of the tunnel about 10 feet in from the entrance where we sat. The young were from one to 18 days old at this time. All but one crawled immediately to the sides of the tunnel and climbed one-half to three feet up the side, where they formed themselves into clusters. When a mother *Corynorhinus* from the rear of the tunnel approached the clusters of young, the babies made audible squeaks which attracted her attention; clusters of young bats which were not squeaking audibly were not

approached by the adults. All the females attracted by the squeaks were ones not carrying young. At first the mother would fly back and forth several times in front of the cluster, next would land on a cluster, crawling about on it as though searching for her young, and finally she would select a baby, cover it with her body and wings, seemingly encouraging it to attach itself to her, and fly off with it. Although the squeaking of the babies may be important in originally attracting the adult, some other sense, perhaps smell, is used in locating the particular baby she seeks, for in each of the six times that we watched a female come and extract her baby from the clusters of young bats, the female first rejected one or two other babies after a momentary contact with each of them. The adults and the babies had been banded on an earlier visit to Aetna Springs, so we were able to certify, by catching an adult as she left a cluster of ten with a baby clinging to her, that she had picked up the one which she had previously been carrying.

Several other times when we have been handling bats during the daytime, mothers have become separated from their young and have been turned loose without them. Some of these mothers showed great concern and returned to circle around us. One even alighted on the cage of young which we were banding. If the young were put on the ground a few feet away from us, or were hung on the wall, some of the mothers returned for them in the manner described above. On one occasion, when some mothers became separated from their young during banding operations, we put them in a cage with the unattached young, hoping that they would single out their own. None of the pairs of mothers and young sought each other out under these conditions.

Lactating females in the wild are usually awake and have a warm body temperature. That this may be due to their selection of warm nursery sites and to their colonial habits is indicated by the fact that the body temperature dropped in a lactating female with young kept in a cage at 70° F. This young grew much more slowly than young in the wild.

The Young

The average weight of ten newborn bats of both sexes was 2.4 grams, and the forearm averaged 16.6 mm. The measurements fall between 2.1 and 2.7 grams, and between 16 and 18 mm. There was no significant size difference between males and females at birth. Further measurements were made on two young bats that died in captivity within 30 hours of their birth. The crown-rump measurement of both these bats was 24 mm.; the skulls measured 13 and 14 mm. long, respectively, and body lengths from tip of nose to tip of tail were 34 and 35 mm.

A newborn *Corynorhinus* is a grotesque creature. The large erect ears that characterize the adult flop over the unopened eyes, and the disproportionately large size of the hind feet and thumb give the young a spider-like appearance. The dried umbilical cord may remain for one or two days. Within the first four days the naked pink body becomes covered with short gray hair; at about seven days of age the ears assume the erect position of the adults, and within a few days after that their eyes are open. Within a few hours of birth they are able to utter

a characteristic sharp, metallic "chirp;" at seven days they can make the squawking noise of a disturbed adult.

When, during our banding procedures, a young bat becomes temporarily separated from its mother, it may stay where it is put and make a series of chirps, or, more often, it will creep about until it finds something up which it can climb, such as a wall or a person. Once it is a few feet off the ground, however, it may hang up in the usual inverted position and wait quietly. On one occasion we saw a young bat crawl out of sight into a half-inch crevice, but this is unusual. The young bats need and have a strong instinct to cling to anything that comes into their grasp, and it is almost as difficult to remove them from one's fingers or clothing as it is to remove them from their mother. Although we have often seen a disturbed mother flying with a young dangling only from one nipple, the young usually clings to the ventral fur of its mother with its well-clawed thumb and feet, as well as to the nipple with its mouth. The position is such that the young probably nurse with their heads hanging down. Most nursing must occur during the day, for from the time that they are born, the young bats are left in the roost at night while the adults go out to feed. We spent part of one night in a nursery roost waiting for the adults to return to their young, and at midnight, when we finally withdrew, they had still not appeared. It is not likely that our presence was keeping them away, since there was much traffic of other bat species (particularly night-roosting *Antrozous*) in and out of the attic, and the adults were found there with their young again the next morning.

The growth of young *Corynorhinus* is quite rapid, and within a month of their birth the young are almost full-grown. The length of the forearm was found to be the best measurement to use in correlating the size of the young bats with their age, and from such measurements Figure 7 was constructed in the following fashion, making use of wild, banded bats in the Aetna Springs and Inverness colonies in 1949 and 1950.

Six newly born bats were chosen with which to start our graph. These individuals were either ones that were born in the holding cage while their mothers were being banded, ones that had been born within a few hours of our visit to the colony, as indicated by a wet, fresh, umbilical cord, or were the smallest ones among a long series of nursing young. That premature young are not included is indicated by the fact that the smallest ones were still alive and thriving when examined a week later. Having determined the size of the forearm at birth, the forearm measurements of four individuals of known age were then plotted. These are the solid symbols at six, seven, and nine days. Then, having estimated from previous calculations that growth of the forearm during the first two weeks was roughly linear, we fitted a straight line to the ten points already established. This line permitted us to estimate the age of any *Corynorhinus* with forearm up to about 27 mm. in length, and thereby to extend the graph in the following manner: a bat with a forearm of 21 mm. (four days old, by inspection of the graph), ten days later had a forearm 35 mm. long. This observation allowed us to put down a point at 14 days, 35 mm. After sufficient points had been placed in this fashion, the original curve could be extended a little further, then the process

repeated. A single measurement of a female known to be 25 days old (solid symbol) fits into the curve well.

Forearm length is a reliable indicator of age up to about three weeks. Growth is rapid, however, and before four weeks the forearm is so close to adult length that it can no longer be relied upon. No significant difference could be detected in the growth rate of the Aetna and Inverness colonies, so the data are combined. The smaller size of the forearm of the males becomes apparent late in development. The lines representing length of forearm of adult males and females in Figure 7 result from averaging the measurements from 22 museum study skins of each sex from the same region as the colonies studied.

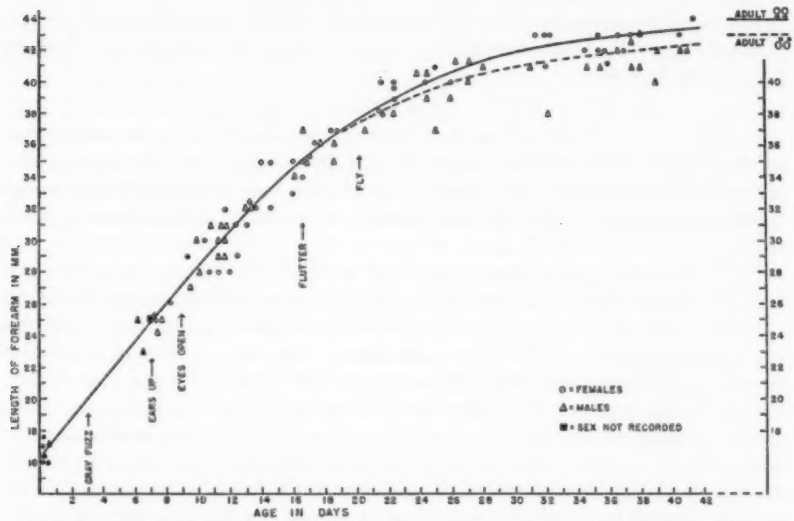

FIG. 7.—Growth of the forearm in *Corynorhinus*. See text for method of constructing this curve.

Up to the age of 16 days (forearm less than 35 mm.), while the growth curve is approximately linear, the forearm lengthens 1.2 mm. per day. During this time, age can be estimated in the field by the formula: age in days = (forearm length in mm. − 16.5) × 0.86.

Young *Corynorhinus* can fly at about two and a half to three weeks of age, and at six weeks of age some young fly out at night as do the adults. When adults are disturbed in the daytime, they may fly with attached volant young weighing as much as six grams, which is about two-thirds the weight of the mother.

As stated above, the stomach of one 42-day-old bat was full of milk, and lactation probably continues to supplement the feedings of bats as much as two months old. The summer colonies start to break up in August, when the older young are a little over three months old. Adults that have lost their young tend

to leave earlier than do lactating females. Our records of the Inverness bat colony show some independence between the movements of the adult and immature bats as early as August 10, for six young bats born before our visit on May 30, 1949, had already left the colony in August of that year, although their mothers remained. Also, two immature bats, whose mothers had already left the colony, were present in August.

The evidence about the sequence of departure from nursery colonies is somewhat contradictory. At Aetna Springs we have observed both in 1949 and 1950 that the young male bats tend to leave the colony earlier than the young females, and that the adult bats tend to leave earlier than the immatures. However, the Inverness colony behaved somewhat differently, for, although young males tend to leave before young females, the young tend to leave before the adults. Some, perhaps the young females especially, wander back to the colony site after the main group has left.

Sex Ratio

Because of the differences in the habits of males and females the only trustworthy figures of sex ratio are those obtained by making counts in nursery colonies before the young are old enough to fly. In the Inverness and Aetna Springs colonies from 1948 to 1950 there were 128 males and 126 females too young to fly.

The closest approach to an accurate sex ratio of fully-grown *Corynorhinus* is probably that of the bats wintering in the Mt. Lassen tunnels, since all the bats in the area probably must take refuge in tunnels. If it be assumed that these bats are a random sample of the winter population, then the sex ratio of the winter population for three years was 404 males and 179 females (69 per cent males). For one season we broke down the Parrish Cave population into young and adult groups. Among the young there were 11 males and 14 females, and among the adults, 58 males and 37 females. These sex ratios suggest that although approximately equal numbers of young of each sex reach Parrish Cave in their first autumn, mortality is subsequently greater among the females, leaving a preponderance of males in the population, but year-to-year banding returns in winter colonies (see below) do not confirm this speculation.

Among bats wintering in the Manhattan Mines, where the temperature does not force all the bats into tunnels, we found a sex ratio of 56 males to 127 females (31 per cent males). The preponderance of males in the Mt. Lassen tunnels, in contrast to the preponderance of females in the Manhattan Mines tunnels, can possibly be explained by the fact that the males are more active, less disposed toward hibernation, than females. In central California many males may pass the winter scattered in buildings, short mine tunnels, etc., whereas in colder regions all must resort to a few satisfactory hibernation tunnels.

Survival

The best direct evidence on survival comes from banded females in nursery colonies. These figures are for females only, since males do not return to the summer colonies and are lost to our records. Allowing for barren females and

losses up to the time of birth, and for the fact that half of the young are males, a colony of 100 females should produce about 45 young females in a season. Actual counts showed an average reproduction of 40 young females per 100 adults for three seasons at the Inverness colony and an average of 50 young females per 100 adults for two seasons at the Aetna Springs colony. However, only about half of these young ever returned to the colonies. Of the young banded in 1947 at Inverness, 46 per cent returned in 1948 and another 8 per cent returned in subsequent years, making a total return of 54 per cent. Of the adults, 73 per cent returned in 1948, and another 4 per cent in subsequent years. In another year at Inverness the returns from one summer to the next were 40 per cent for one-year-olds and 70 per cent for adults. In the one year of observations at Aetna Springs, 38 per cent of the one-year-olds and 81 per cent of the adults returned. Whether dispersal or death is responsible for the large loss of females in their first year we do not know. Of the young that survived their first year at Inverness, 75 per cent returned again as two-year-olds and 80 per cent of these returned as three-year-olds. These percentages are about the same as those for all the adults from one year to the next.

From the above, we may assume an average of 20 female bats added to the colony per 100 adult females each year, and an average survival of 80 per cent of these bats each year after their first. These percentages are just sufficient to maintain the colony at the same size in successive years. The colonies that we have observed have actually stayed about the same size, and few new adults have appeared. Assuming an equal mortality for adults in all age classes gives the following composition for a colony of 100 females:

Age in years	Number of individuals
1	20
2	16
3	13
4	10
5	8
6	7
7	5
8	4
9	3
10	3
11	2
12	2
13 through 19	each year, 1

(median age 3.1, average age 5.0)

The figures beyond the three-year-old age class are, of course, theoretical since we have not yet followed a colony for more than three years.

In the Mt. Lassen and Manhattan Mines winter colonies, between 25 and 31 per cent of the females are young, judging by nipple size (some non-parous adults

may be included in this percentage). Since 45 per cent of the females bear female young (based on Inverness and Aetna Springs figures) it appears likely that much of the loss in the first year occurs before the bats arrive at the winter quarters. Only about 16 per cent of the males in these winter colonies are young, judging by size of epididymis, which suggests either a lower survival in the first year than among females or a higher survival of adult males than adult females.

Of the bats banded in the winter of 1948–49 at the Mt. Lassen caves, we have recovered 53 per cent of the males and 58 per cent of the females in the two subsequent years. These are minimum survival figures, but are not comparable to figures for the summer colonies since the number of bats in these winter tunnels has decreased. Also, many were recovered in 1951 that were not found in 1949, showing that we did not capture the whole population. If we break down the females from the Mt. Lassen caves into age groups we find a recovery of 63 per cent of adults and 44 per cent of young. In the one year for which we have age records of the males, the percentage recovery of young was half that of the adults.

Population Density

Because of the nature of their habits, it is seldom possible even to estimate the population density of bats. An exception is provided by a colony of *Corynorhinus* living on Santa Cruz Island, 20 miles off the coast of California. A nursery colony totalling about 200 individuals was discovered there, and a few adult males were found roosting in other parts of the island. It is probable that these bats seldom if ever left the island. The island contains about 62,000 acres of badly-eroded bare hills, grassland, chaparral, scrub, pine forest, and patches of hardwoods. This allows not more than 310 acres per *Corynorhinus*. The island also supported at least an equal number of *Antrozous pallidus* and an undetermined number of *Myotis californicus*.

Similar data from the mainland are difficult to obtain since it is not known how far *Corynorhinus* flies to feed. The spacing of colonies, however, gives some information on population density. Two nursery colonies in Marin County were 12 miles apart. In Napa County three nursery colonies when plotted on a map fall in a straight line. The central one lies eight miles from a colony to the southwest and twelve miles from one to the northeast. No bat banded in one nursery colony has ever been recaptured at another nursery colony. If we assume that there are no other colonies between these three, then the central colony of 120 females and young might be considered to have a feeding area ten miles in diameter, giving 419 acres per bat. The certain presence of an unknown number of adult males and the possible presence of undiscovered colonies closer than eight and twelve miles means that this estimate of population density, as well as the estimate for Santa Cruz Island, is a lower limit; each *Corynorhinus* probably has available considerably less than 419 acres.

Limitations on Numbers

The number of *Corynorhinus* in a region might be limited by (1) disease, (2) predation, (3) amount of food and water, or (4) the number and size of suitable roosting places in summer and winter.

(1) It is unlikely that disease plays an important role in population control, for we have found only a few dead individuals (usually young) in the roosting places, and only once have we encountered individuals that appeared to be in poor health. This was in the Mt. Lassen caves on January 21, 1951, when two thin males were found hanging in a moribund condition, unable to awaken and fly.

(2) Predation likewise is unimportant in controlling *Corynorhinus* populations. No animals have been reported preying upon *Corynorhinus*. We have three records of house cats bringing in dead specimens, but it is not known how or by what these bats were killed.

(3) Little is known of the feeding habits of *Corynorhinus* except that they eat moths and other insects (probably flying insects for the most part). Because of this ignorance, and because estimates of the abundance of possible food species are not available, one can only guess at the importance of food supply in limiting numbers.

(4) With regard to roosting sites, we have found no nursery or winter colony site that did not seem large enough to shelter many more bats than were present, so some factor other than the size of occupied roosts must operate in limiting the number of bats in each colony. Possibly food supply is the limiting factor here. The *total* population of *Corynorhinus* then appears to be limited by the remaining factor: the number of suitable roosting sites. If this is true, then *Corynorhinus* must have been a rare bat in California a few centuries ago because nearly all the colonies with which we are now familiar are in man-made structures. We have never found *Corynorhinus* roosting in hollow trees, and these, plus the few natural caves in California, probably were the most suitable roosting places for this bat prior to the white man's arrival.

In view of all these considerations it seems likely that the population level of *Corynorhinus* depends upon the number of suitable winter roosting sites and the number of summer roosting sites surrounded by adequate feeding territory. Beyond a certain point, increasing the number of roosts does not increase the population. This has been demonstrated by the large numbers of mine tunnels dug in the western foothills of the Sierra Nevada in the last half of the 19th century (tunnels that have subsequently been abandoned). The creation of so many roosts that appear to be suitable for *Corynorhinus* does not seem to have resulted in a larger *Corynorhinus* population in that region than in many other parts of the state.

How new nursery colonies become established is not known. If a satisfactory building becomes available near an already-established colony, the colony does not divide and make use of both; the entire colony uses either one or the other, or alternates between the two. Consequently, for a new nursery colony to become established some females either through chance, faulty navigation, or some inner drive must find a suitable roosting place outside of the range of an existing colony. Furthermore, it is likely that several females would have to arrive at this place in the same season for gestation to proceed normally, since females are gregarious and may depend upon clustering to keep their body temperatures high. The colonies that we have studied have not increased in size from year to year. If the species is to increase in number, the number of colonies must increase.

Summary

Dissections were made of 139 male and 288 female *Corynorhinus* from California, and over 1500 others were banded and released. About 70 were kept in captivity for various lengths of time.

Young and adult females gather in the spring in colonies as large as 200 individuals in warm, dark places such as attics and mine tunnels, and remain there while the young are born and raised. If disturbed in their roosting place, an entire colony may move to an alternate roost nearby. The females return to the same site year after year. Adult males are seldom found in the nursery colonies, and during the spring and summer while the females and young are in nursery colonies the males are solitary. The nursery colonies begin to disband in August and September and both sexes begin to congregate in hibernating places such as caves and mine tunnels. The wintering sites must be cold, but not much below freezing. Large numbers of *Corynorhinus* have been found hanging in caves at temperatures as low as 28.5° F. The temperature in one cluster of 31 bats was 32° F. Hibernating *Corynorhinus* awaken from hibernation occasionally and fly about for a few minutes, then promptly return to a torpid state. Males accumulate less fat and are more likely to be active in winter than females. In central California some individuals, especially males, do not come to hibernation tunnels in the winter but fly outside in temperatures at least as low as 37° F. In one instance the hibernation site was only a few hundred yards from the location of a summer nursery colony. Banding records have given no indication of long migrations.

The testes of young males four months old enlarge in the autumn and may form a few spermatozoa, but growth of the testes and spermiogenesis are not nearly as extensive as in adults. The sex accessories also do not enlarge as much as in adults. It is unlikely that young males copulate in their first year. The testes of the young and adults are small during the winter, begin to enlarge again in the spring, and reach a maximum size in September. Final stages of spermiogenesis are accomplished rapidly; the spermatozoa leave the seminiferous tubules and are stored in the epididymides, and the testes then regress before winter. Adult males can be distinguished from young by the bulging epididymides of the adults and by their large sex accessories. Motile spermatozoa remain in the epididymides all winter and into the spring. The spermatozoa are still capable of fertilizing six months after they have been formed.

The interstitial tissue of the testis is remarkably hypertrophied in young males and in adults in summer. It is least developed in autumn and winter when the sex accessories are largest and when copulation occurs. Most copulations occur in the winter roosting place, but some females are inseminated before they arrive at the hibernation site. Some, perhaps most, copulations are accomplished while the females are hanging torpid. All young females as well as adults are inseminated before the end of November, although copulations continue through the winter.

Young or non-parous females can be distinguished from old or parous females by nipple size and condition of the uterus.

A single Graafian follicle begins to enlarge in the autumn before copulation and remains practically the same size throughout the winter. It enlarges further in the spring at the time of ovulation. In some cases ovulation occurs while the females are still at the winter roost, or it may occur after they have left. Ovulation is not readily induced by removing *Corynorhinus* from hibernation to warm rooms before mid-February. Injection of human pregnancy urine induces ovulation. Spermatozoa stored in the uterus of the female in winter remain motile for at least 76 days.

Early development of the embryo is quite slow in central California, but under certain temperature conditions probably proceeds more rapidly. Implantation of the embryo is almost always in the right horn of the uterus although ovulation occurs with almost equal frequency from either ovary. Gestation is variable and lasts between 56 and 100 days. Its length probably depends upon the mother's body temperature which in turn depends in part on the surrounding temperature and upon the presence or absence of other bats around her.

The young at birth weighed about 2.4 grams and forearms averaged 16.6 mm. long. Average birth dates for two colonies in central California were in late May and early June. Year-old females bear their young slightly later in the season than do adults. Only one young is born to each female each year; many females have been observed to bear young three years in succession. The young are able to fly at three weeks of age, but continue to nurse for several weeks longer. The young are left behind in the nursery colony when the parents fly out to feed. When the mother returns she selects her own baby out of a large cluster of young and nurses it during the day.

The sex ratio at birth is equal, but because of different habits of males and females it cannot be measured for the adult population.

A colony of 100 females produces about 45 young females each year. Twenty of these 45 return to the nursery colony the following spring. What happens to the rest we do not know. About half of the females in a nursery colony are more than three years old and many are probably more than ten years old.

The closest nursery colonies with which we are familiar are eight and twelve miles apart. A rough estimate of population density indicates that each *Corynorhinus* has available somewhat less than 310 acres. The population is limited neither by predation, disease, nor size of winter or summer roosting sites, but probably by the number of suitable roosting sites surrounded by an adequate food supply.

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OBSERVATIONS ON THE PILOT WHALE IN CAPTIVITY

By Henry Kritzler

On the morning of October 6, 1948, forty-six pilot whales, *Globicephala macrorhyncha* (Gray), swam ashore at St. Augustine Beach, Florida. They were discovered at 7:15 A.M. by Mr. Frank Canova, of St. Augustine. He immediately drove to the writer's home and transported him to the beach. Four of the animals, of which only one survived more than nine days, were removed to a tank at Marine Studios, Marineland, Florida. The writer has already published a brief, popular account (Natural History, 58 (7): 302–8, 331–2, 1949) of his observations on the stranding and on the surviving specimen. With regard to the latter, this report dealt with only the first three of nine months that the whale lived in captivity. A more comprehensive record is presented herewith.

OBSERVATIONS ON THE STRANDING

The writer arrived at the scene of the stranding about fifteen minutes after it was reported to him. The whales were scattered over a mile of beach. Most of the individuals were gathered in two groups, one of which was close to each end of the distribution. This dispersion suggests that the original school may have been fairly large and that as the whales radiated in panic from some powerful source of stimulation, those whose courses took them shoreward coalesced in two groups following separate leaders. No clue as to the direction they were swimming when they grounded could be obtained, of course, as the individuals were oriented in all directions. This, no doubt, was due partly to their having thrown themselves about when they struck the beach and partly to wave action. All but the very smallest specimens lay below the low water mark. Since the falling tide was almost at the ebb, it was evident that the stranding could have taken place only a short while before it was discovered. The fact that only one was dead substantiates this hypothesis. This animal, one of the largest males, bore no marks to suggest how it had been killed, so it was concluded that it had been drowned. It lay farther out than the others. If the whales had beached during the preceding flood, more would have drowned before they were discovered. Unlike many smaller dolphins, whose body shape permits them to rest on their ventral surfaces, the pilot whale is forced to lie on one side when ashore or in water too shoal to float it. Under such conditions, the rising tide inevitably covers the blowhole before the whale is able to right itself.

The whales varied in length from seven and one-half to just under twenty feet. None of the females was more than fifteen feet long. The sexes were almost evenly divided. The immature males resembled the females in body form. The adult males, aside from the difference in inguinal morphology, could easily be distinguished by the bulbous nasal protruberance which overhangs the tip of the snout only in that sex, by the prominent hump extending from just behind the blowhole to the base of the dorsal fin, by the great size of the dorsal fin, and by the considerably more attenuated appearance of the pectoral fins and flukes. The males are also characterized by a pronounced crest on the dorsal edge of the

caudal peduncle. Their bodies are rather deeper in cross section than are those of the females. There is no doubt that the sexes of adult pilot whales may be easily ascertained at sea by an observer familiar with these characters.

None of the females was lactating. Neither of the two females which were eventually dissected was carrying a fetus. All the animals were passing bright green, semi-fluid feces. The color was attributed to bile pigments. The flow of bile in toothed whales, at least, is continuous (there being no gall bladder) and abundant, a phenomenon which is related to the dependence of these animals on a great supply of fatty food.

All the animals lay perfectly still when first discovered. However quietly they lay, the fact that the uppermost eye of each was wide open indicated that they were not sleeping. The Delphinidae close their eyes when they sleep. When the skin of any one of them was lightly touched, the eye promptly closed, indicating that the skin is quite sensitive to tactile stimuli. This was eloquently substantiated later by the surviving specimen. Touching them or handling them elicited no resistance of any sort. This could be attributed either to exhaustion or to the fact that dolphins generally tend not to struggle when forcibly restrained outside of their natural medium.

Most of the large ones drowned as the tide rose. This was accompanied, as may be supposed, by renewed struggling, which, for the most part, served only to hasten the end. As the pilot whale cannot turn its head, the only way in which the animals could react to the rising water was to thrash it with their tails. No sounds other than retching associated with the regurgitation of water could be heard. A number of medium-sized specimens survived until late in the afternoon, having been washed farther up on the beach. One female, about twelve feet long, was dragged into water deep enough to float her, but she could not be induced to swim seaward.

The whales which survived until late afternoon were badly sunburned. Many had enormous blisters. The two smallest specimens, both males, had been transported by truck to Marine Studios in the early morning. A slightly larger female was moved to the tank in the early afternoon and a half-grown female—badly sunburned—was taken later. It was evident from the manner in which she struggled that the sunburn was attended by heightened sensitivity to tactile stimuli. Almost all of the remainder was hauled to a rendering plant during the night.

OBSERVATIONS ON THE FOUR CAPTIVES

The four pilot whales which were transported from the beach were immediately placed in a large circular tank in which bottlenose and other smaller dolphins had been exhibited for some years. The drive for schooling or herding which seems to be particularly well developed in the pilot whale was promptly made manifest by the close formation in which they gathered. Only one, the smallest, which, incidentally, was the sole survivor after nine days, separated itself from the group. The size of this specimen suggested that it was very young—probably an infant of the year and perhaps not even fully weaned. Its tendency to wander

away from the others closely paralleled the manner in which young bottlenose dolphins steal away from their mothers.

Daylight hours were devoted almost entirely to slumber; this took place at the surface with the blowhole, the anterior portion of the back, and the dorsal fin exposed. While sleeping, their bodies were almost always to some extent in contact. No effort was made to associate with the bottlenose and spotted dolphins, not that these would have welcomed such mingling. It was apparent from the first that the bottlenose dolphins viewed the new arrivals with distrust. At no time, however, did the pilot whales exhibit any behavior which could furnish justification for this. Their meekness may only have been due to fright and exhaustion. When fighting broke out during the second night, the whales seemed to be only on the defensive.

The two females were the first to die. Their early demise was considered due to the combined effects of exhaustion and prolonged exposure to the sun. From this instance, and from many others involving smaller dolphins, it has been found that if a cetacean is removed from the water and exposed to subtropical sunlight, or even summer temperatures in the shade, irreparable damage to overheating will result, unless the skin is kept moist with cool water. Mysticetes, with their abbreviated ribs, usually suffocate when stranded, but the smaller odontocetes, at least, seem to experience no particular difficulty in respiring on land. The larger of the two young males lasted eight days and the writer is certain that it would have lived longer if acceptable food had been obtained in time. The only food available when the pilot whales were placed in the tank was the fish which are fed to the dolphins. The pilot whales showed no interest whatever in these, nor did they attempt to catch any of the living fishes exhibited in the tank. None of the three which died consumed any food, as far as could be ascertained. On the ninth day a small quantity of frozen squid was secured. These were rejected by the survivor when they were presented to it during daylight hours, but it took them eagerly after dark.

OBSERVATIONS ON THE SINGLE SURVIVOR

Feeding.—Until an ample supply of squid could be obtained, the whale was placed on a daily ration of twenty pounds. When a carload had been placed in storage, the amount was raised to forty-five pounds each day. This was divided into three meals—one in mid-morning, one in late afternoon, and the third just after midnight.

At first the squid were thrown to the whale. The attendant had to take care to drop each morsel near enough to enable the animal to secure it before it could be filched by the more active fishes and dolphins. It was quickly found that the squid had also to be placed a little to one side of the whale's course, as its bulbous nose, laterally placed eyes, and immovable head made it impossible for it to see directly ahead. However, it must be pointed out that this precaution was made only because of the element of competition provided by the other animals, for these anatomical features also precluded the whale's seeing the food as it was taken into the mouth. It was quite apparent that the food may be identified

by touch or taste, or by the two senses acting in concert. During the first week or so, the attendant walked around the rim of the tank dropping the squid to the whale as it swam. When it was felt that the animal had recovered from the effects of the stranding and its subsequent fast, its training began. The attendant then remained on a small platform jutting over the water from the tank's rim, dropping a squid to the whale only when it passed. It took the whale only a few days to learn to associate feeding with the platform. It then cruised around in small clockwise circles (the circulation of the tank being counter-clockwise) and a squid was dropped to it or placed between its jaws each time it passed the platform. The circling was soon dispensed with. On hearing the sound of the bucket being placed on the platform, the whale would present itself before it, lower its tail, raise its snout above the surface, and receive the squid one by one. There was, from that time on, no longer any concern about other animals stealing the whale's food. If a squid was held a little higher than the animal's buoyancy would raise its snout, it would push itself upward.

It soon became apparent that the whale had become adjusted chronologically to the feeding schedule, for it was noted that for an hour or so before feeding time, it would commence cruising around the periphery of the tank, rolling on one side to look up with one eye either at the platform or at the railing at the other side of the tank. It was at the latter point that the attendant could first be expected to appear as he brought up the food. It was also apparent that it had become able to distinguish between the uniformed attendant and other persons, for as soon as he appeared, the whale would swim around the periphery of the tank abreast of him or would cut diametrically across to await the attendant with its mouth open. The attendant always rinsed the pail at the end of the meal. The whale was not long in grasping the significance of this. Not until it was done would it swim away from the platform.

As indicated in the foregoing, the whale showed no interest in the small carangid fish used to feed the dolphins, nor in any of the living sea bass, grunts, pinfish, or other fishes in the tank. Shortly after it was conditioned to hand feeding, an attempt to vary its diet was made by giving it herring. This was promptly dispensed with when it was seen that it digested them only with difficulty. It was immediately replaced on the diet restricted to squid. Nevertheless, after several months the whale learned to eat fish. The dolphins are fed fish three times daily, and during these feedings, the whale, whose meals were scheduled for other hours, had nothing to do but look on. The dolphin feedings are characterized by great activity and excitement. The animals leap from the water to take fish from the attendant's hand, or swim full speed around the tank to secure those which he throws on the surface. It was obvious that at first the whale's chief concern during these feedings was to avoid collision with the dolphins. But it was, of course, inevitable that, from time to time, it would be near enough to a thrown fish before a dolphin could reach it. Eventually it began to show active interest in these fish. At the onset of this development, it would content itself with carrying a fish in its mouth for a while, to toy with it much as young bottlenose dolphins do when they begin to be weaned. After a

while, the fish would either be discarded or swallowed. Before long, there was no doubt that during the dolphin feedings the whale was actively seeking thrown fish. There was a noticeable decrease in its interest in squid from that time on.

In May, 1949, a female bottlenose dolphin with a week-old infant was introduced into the tank. The mother was quite timid, so much so that it was afraid to compete for food with the others during the scheduled feedings. In order to assure the infant of adequate nourishment, the attendant fed the mother by throwing fish to it when the other dolphins were being fed beneath the surface by a diver. He always threw the fish from the same place at the tank's periphery, hoping thereby to condition the dolphin just as the whale had been. The whale's prompt appreciation of the significance of this change in the schedule was shown by the fact that each time the special feeding took place, it appeared just below the attendant's position and begged for fish. It could be induced to raise fully half its length out of the water, a maneuver requiring great effort considering the tadpole-like shape of the animal.

It was very quick to take advantage of another special feeding, this one being for a group of nine or ten sea drums, *Pogonias cromis*. These large sciaenids are exclusively bottom feeders. Such fishes would starve if they had to depend on food thrown into the tank from above, as very little of this ever reaches the bottom. Each day, therefore, a bucketful of cut squid was upset on the bottom. When it was seen that the whale had preempted the drums in this arrangement, the drum feeding was rescheduled for after dark. When picking the pieces of squid off the bottom, the whale assumed a vertical position, with its head down.

Play.—Dolphins which have become adjusted to conditions of captivity spend almost all of their time, when not sleeping or eating, at play. The aimless swimming that characterizes the behavior of reptiles and most fishes is not seen in these animals. The pilot whale, after it became adapted to the essentially diurnal regimen of the aquarium, exhibited as great a capacity for play as any dolphin. Becoming more active during the day than in the night may be considered evidence of the pilot whale's adaptability, since it was apparent from the first that *Globicephala* is essentially a nocturnal animal. It has already been mentioned that the whale first took food at night; most of the training which resulted in its learning to be hand fed was done at night, and, until this was achieved, it spent most of the daylight hours resting or sleeping in the winter shadow of the south wall of the tank. This afforded it a measure of segregation from the dolphins which prefer the sunlit northern portion.

The pilot whale first began to exhibit play behavior by rubbing itself on turtles. This was performed either by swimming alongside a large loggerhead or green turtle allowing the reptile's flipper to stroke its head or body, or by swimming past the turtle with its body in contact with some projection on the turtle's carapace. This form of amusement became complicated by the fact that the claw on the anterior edge of the turtle flipper abraded the whale's skin, chiefly on the eyelids. The fact that from this point on the whale exerted itself to bring the affected areas into contact with the turtle suggested that it suffered some irritation. A vicious cycle resulted, the lesions increasing in size. The situation was

ameliorated somewhat by inducing the whale to rise higher from the water at feeding time, so that an anaesthetic ointment could be applied to the affected areas.

New sea water is continually pumped into the tank under great pressure through a number of jets situated at the bottom. The whale soon learned, probably by imitating the dolphins, to thrust its snout into one of these blasts of water, apparently to enjoy the massaging effect of the current flowing past its body.

One of the most characteristic play patterns exhibited by the dolphins is toying with small objects such as feathers, bits of paper, fragments of shell, and so forth. Such objects may be played with for hours at a time. If dropped, the animals show remarkable ability to recover a particular item even though there may be many others of similar appearance all around. The pilot whale first began to develop this play pattern by going to the drain vortex in the center of the tank, there to take into its mouth a piece of flotsam. It would then swim a short distance away, release the object and follow it as it was swept back into the whirlpool. This would be executed repeatedly until its attention was distracted by a passing turtle or a playful dolphin. The whale showed more interest in this sort of play during the first few months, and it became very quick to notice almost any small object that was dropped into the tank. It toyed in this manner for an hour or more, one time, with a briar pipe accidentally dropped into the tank by a visitor.

During the period covered by this report, it was decided to provide the dolphins with some sort of inflated rubber toy. Rubber balls small enough to be grasped were ruled out as a potential hazard. Larger balls seemed undesirable as it was thought that the dolphins would be unable to manipulate them. So a number of inflated inner tubes, of the sort used in wheelbarrow tires, were placed in the tank. The valve of each had been replaced by a hot patch. The dolphins soon became very adept at playing with the tubes. The usual procedure was to rise up from beneath a floating ring, spear it with the snout, and, as momentum carried the anterior end of the body clear of the surface, hurl it into the air with a shake of the head. The whale attempted to imitate this behavior, but anatomical limitations precluded achievement of the same result. Lacking a long, slender snout, it was unable to spear the rubber rings. It substituted for this either by rising up beneath a tube and swimming at the surface with the object perched on its nose, or by grasping it with the teeth to carry it to the bottom, release it, and follow it back to the surface. Occasionally it would roll over, thrust one flipper through a ring, and swim about upside down at the surface.

McBride and Kritzler (Jour. Mamm., 32: 251–266, 1951) have described the manner in which infant dolphins swim with adults, playing about the latters' heads much as pelagic dolphins play about the bows of ships. The whale seemed to welcome this association with a contemporary bottlenose infant, especially when it resulted in bodily contact.

The dolphins engage in mock fighting and games of chase at all seasons of the year. In the spring, particularly in April, when mating activity is at its height,

real fighting occurs, chiefly among the males. When the dolphins became adjusted to the presence of the young pilot whale and permitted it to mingle freely with them, they often included it in their mock battles. In either playful affrays or in real ones, the whale was always on the defensive. Its lesser agility and immaturity placed it at a considerable disadvantage. Although, at the time it was killed, it was somewhat larger than the largest bottlenose, it was no match for an adult of either sex. It could swim as rapidly as they, but it was incapable of performing the quick turns and other gyrations which are indispensable to the fish-eating dolphins. When set upon by one or more of the latter, it would usually roll over, apparently to shield its belly from impact. The dolphins deliver blows either by rapping sideways first with the snout and then with the tail as they swim by, or by ramming head on with the jutting tip of the lower jaw. The whale often threw itself clear of the water in these encounters in order to avoid blows. During the first five months of the whale's captivity, it seemed that all such episodes could be characterized as play. It was thought that the whale was stout enough to escape real harm in these fracases. However, one morning in April, it was found that the young whale had been thoroughly beaten during the night. There was a great bruise on its nose and the skin of its tail was crisscrossed with parallel lacerations which can only be inflicted by dentition such as that of dolphins. The bruise was caused by collision with the feeding platform. The three adult male bottlenose dolphins, especially a very old one, were responsible. At intervals during that morning, they repeated their attack. During the following night, the water was lowered to knee depth and a crew of about eight men caught and removed the three bottlenose males. Two were set free, eventually to be replaced by newly caught females, and, after a lapse of several days, the third was returned to the tank. The bruise and lacerations affected only the superficial layers of the whale's skin, but it was later found that several ribs were broken. A noteworthy result of this incident was the whale's prompt reversal to nocturnal behavior—sleeping by day and swimming slowly about by night. Normal swimming movements seemed to be attended by pain. There was a prominent cut just at the point of union between the caudal peduncle and the under surface of the flukes. Up-and-down motion of the tail, which is the usual means of propulsion in cetaceans, kept opening this wound. Until it healed, the animal swam by fish-tailing, that is to say, by wagging the tail from side to side. No play behavior of any sort was indulged in by the animal during the period of convalescence. As the wounds healed, it gradually regained confidence and resumed being more active during the day.

Sounds.—That cetaceans have a well-developed auditory sense may be inferred from the structure of the ear and of the brain. It is entirely reasonable to assume, on purely morphological grounds, that communication by sound is equally well developed. Indeed, it is difficult to suppose how else these highly social animals might communicate. In recent years, a few reports on cetacean sounds have appeared in the literature. The most outstanding of these are those of Schevill and Lawrence (Science, 109: 143–144, 1949, and a phonograph record published by the Woods Hole Oceanographic Institution) who have recorded

the sounds produced by the white whale or beluga, *Delphinapterus leucas*. Fraser (Nature, 160: 759, 1947) has also published a note on sounds emitted by dolphins. McBride (Nat. Hist., 45: 16–29, 1940) and McBride and Kritzler (*loc. cit.*) have discussed communication by sound in the bottlenose dolphin.

Five distinct sorts of sounds were attributed to the pilot whale. All of these involved use of the respiratory tract, or so it may be assumed. At no time was this animal observed to create sound by clapping its jaws or by whacking the surface with its flukes.

The sound most frequently emitted by the pilot whale was a high-pitched squealing or whistling practically identical with that produced by the three other species of dolphins which have been exhibited in the tank. The writer ventures to predict that this whistling may eventually be found to be characteristic of all dolphins, if not of odontocetes generally. As a rule, small quantities of air escape during its generation, this being indicated by a stream of small bubbles emanating from the blowhole. Its propagation is not limited to beneath the surface. There is no doubt that it is a means of communication, as it is much used at times of excitement, whether due to fighting, fright, pain, or competition for food. After the young pilot whale was injured by the male bottlenose dolphins, it would rest at the surface and whistle continuously.

Occasionally the pilot whale produced a loud smacking noise with the blowhole exposed to air. This was achieved essentially in the manner in which a kissing sound may be produced by human lips. The tightly pursed lips of the blowhole were sucked in a bit just before they opened and the sound was produced. The significance of this performance is open to question. It occurred only at times of comparative tranquility, when the animal was resting.

A third sort of sound, also evolved while the whale lay quietly at the surface, was also produced by the lips of the blowhole. It resembled a loud, prolonged eructation, and evidently was produced by the gradual emission of air past the not very tightly pursed lips of the blowhole. Inhalation followed immediately. No function could be ascribed to it.

The fourth sort of sound was produced only under water and could not be detected by a casual observer. This was a peculiar, grating snore similar to a sound much used by the dolphins when feeding or fighting. A similar sound may be heard in the white whale record of Schevill and Lawrence. No bubbles escape during its emission. Inaudible in air, it was easily detected with a hydrophone. It is reminiscent of the noise produced when a large door is slowly swung on rusty hinges.

The most noteworthy sound produced by the pilot whale was quite unlike anything which the writer has ever heard in the dolphins. It sounded like the peevish whining of a young child. It had something of the character of the crying of young porcupines or beavers. It was heard only when the whale was made to elevate its snout higher out of the water than its buoyancy would permit. During the day, incidental noises muffled it completely as far as hearing it with the unaided ear was concerned, but during the night, when all was quiet, it could be heard plainly. Day or night, it was clearly heard with the hydrophone.

Sexual behavior.—McBride and Kritzler (*loc. cit.*) have alluded to the sexual precocity of the bottlenose dolphin. It was their opinion that to some extent sexual behavior in infant dolphins may only be an example of their penchant for imitating the adults. The young pilot whale was very likely in its first year, this being deduced from its size and its dentition. Occasional erections and only one attempt at copulation with an adult female bottlenose were noted. If the whale had been older, it is quite likely that instances of sexual behavior would have been observed more frequently despite the fact that there were no others of its species in the tank.

The death of the whale.—Late in June, 1949, during a dolphin feeding, one of them rammed the whale with such force as to hurl it clear of the surface. From then on it seemed to experience difficulty in feeding. Although food was offered to it at all hours, it would take only a little at a time. During the night of July 5 there was a great commotion in the tank, and on the following morning the whale was found dead. Autopsy revealed that the left ramus of the mandible was broken—a ready explanation for the loss of interest in food. The whale had not starved to death (although the rate at which a fasting cetacean loses weight is very high) for it had thick layers of body fat beneath the blubber. Its death is presumed to have been caused by drowning.

DISCUSSION

The social order.—The tendency to form well-integrated social groups seems to have attained a higher level of development in the pilot whales than in any of the other species of dolphins which have been observed by the writer. They are reported by Norman and Fraser (Field Book of Giant Fishes, Whales and Dolphins, G. B. Putnam's Sons, New York, 1949) to occur in schools numbering at times in the hundreds. While the observations reported here furnish few data directly concerned with the social behavior of pilot whales, several deductions may be offered. The fact that, at the scene of the stranding, an apparently uninjured, well-grown female could not be induced to swim seaward when it was placed in water deep enough to float it, suggests that survival is so closely integrated with the structure of the social organization that the individual cannot act for itself. This is attested to by the manner in which these animals give way to panic, which seems to have taken place in this stranding and certainly does in those caused by humans who use *Globicephala* for food. Murie's (Trans. Zool. Soc. London, 8: 235–301, 1874) account of a man-induced stranding is a case in point.

The compact grouping of the four captives, so close that their bodies were almost always to some extent in contact, particularly when they slept, attests to the dependence of the individual upon the group for security. The attitude of sleeping in bodily contact recalls the manner in which sea lions rest their heads on one anothers bodies while sleeping. Awaken one and all are promptly alert. If this intimacy characterizes the slumber of pilot whales at sea, the survival value is immediately apparent. The inoffensiveness which was displayed by the four captives may be a characteristic of the genus or it may only have been due

to the fact that the group consisted only of exhausted and frightened females and very young males. It would be interesting to know how a mature male pilot whale would react to the aggressiveness of the bottlenose dolphin.

Food preference.—Norman and Fraser (*loc. cit.*) state that cuttlefishes form the food of the pilot whale. This is certainly supported by the facts that at first the captive showed no interest in any food but squid, and that squid beaks were found in the intestines of two which ate nothing after they were collected. It is proposed by the writer that the pilot whale is morphologically and psychologically adapted to feeding on squid rather than on fish. Squid are found in huge, densely-packed aggregations. They are apparently negatively phototropic as they are found close to the surface only at night. When frightened, they are capable of bursts of speed by jet propulsion, but their normal locomotion is quite slow. They are not capable of performing quick turns. With these facts in mind, it will be seen that these cephalopods are more suitable prey for the pilot whale than are fishes. The dentition of *Globicephala macrorhyncha* is much reduced, there being only seven to nine pairs of functional teeth in each jaw of adult animals. While these teeth are by no means rudimentary, they are much smaller in proportion to the whole animal than are the much more numerous teeth of the fish-eating dolphins. Reduction of dentition seems to be a corollary of the squid-eating habit in Odontocetes, this being particularly marked in the sperm and beaked whales. A squid firmly held, even in toothless jaws, cannot move its soft body in such a way as to enable it to escape. The pilot whale's great, fleshy jowls and active tongue are used to manipulate the food once capture is effected with the jaws. The immovable head, the monocular vision, and the relatively inflexible body seem to limit the pilot whale to the pursuit of food organisms which are not capable of intricate maneuvers. In contrast to this, the bottlenose dolphin is capable of turning its head in any direction, and its eyes are so placed as to give it some measure of binocular vision. The black coloration may be an adaptation to nocturnal pursuit of prey, the squid being equipped with excellent vision.

If, indeed, pilot whales feed principally in the night, the manner in which they find the squid is problematical. Although many squid are luminescent, vision is probably not particularly useful in this regard. A question which has intrigued the writer for some time is whether or not some form of echo-ranging is employed. A plausible basis for an affirmative finding in this respect is found in the very high frequency squeaks and whistles which have now been observed in several genera of toothed whales. Fraser (*loc. cit.*) has shown that dolphins seem to be sensitive to frequencies above the range of the human ear. A further point in question is the manner in which the individual pilot whale fixes upon a particular squid as the immediate object of its attention. It is altogether likely that the squid are found in such compact masses that the whales have only to swim through the school taking whichever individuals they run into. It is evident from the observations reported here that it is not necessary for a pilot whale to see a squid in order to identify it, although this is certainly facilitated by vision. When the captive was hand fed, its eyes were generally below the surface, so it is probable that the tactile and gustatory senses incor-

porated in the snout and mouth are all that are necessary for the identification of food.

If, indeed, the wild pilot whale is exclusively a squid eater, then the eventual, habitual eating of fish by the captive was an example of adaptive learning. It must be borne in mind that the only fish it ate were those thrown or dropped into the tank by the feeding attendant. It never attempted to catch any of the hundreds of small fishes which lived in the water around it. However, it must be borne in mind that fishes have been found in the stomachs of other Odontocetes which are primarily dependent on cuttlefish.

The senses.—Kellogg (Quart. Rev. Biol., 3: 29–76, 174–208, 1928) contended that, because cetacean eyes are adapted to underwater vision and seem to be incapable of accomodation, these animals must be myopic in air. This has been deduced from the morphology and optics of the eyes of preserved specimens. In this connection, it should be stated that Kellogg held that the cetacean eye is immovable, a contention which is distinctly at variance with the present writer's observations on four genera of dolphins. However, if, in fact, these animals are nearsighted in air, their powers of perception or visual discrimination are such as to enable them to overcome this handicap to a remarkable degree. It may be that the highly convoluted cerebrum endows the dolphin with a learning capacity which compensates for the alleged aerial myopia. They seem to be able very readily to associate what they see above water with very discreet situations. The watching for and apparent recognition of the uniformed attendant by the pilot whale is a case in point. The writer has on many occasions seen wild bottlenose dolphins herd mullet, *Mugil cephalus*, toward a steep bank of an estuary where the fish are induced to jump out of the water directly into the waiting dolphins' mouths. The catching and highly accurate throwing of various objects by the bottlenose, recently well described by Mertens in his "Zwischen Atlantik und Pazifik" (von D. Gundert Verlag, Stuttgart, 1951), call for a considerable degree of aerial visual coordination. Norman and Fraser (*loc. cit.*) describe the manner in which killer whales seem to scan ice floes for seals, and ice-bound rorquals apparently search for open leads.

Hearing seems to play an important role in the lives of cetaceans generally. The temporal lobes of the dolphin brain are very large, so much so that the breadth of this organ exceeds its length. This, plus the variety of sounds produced by *Globicephala*, suggests that it is largely if not essentially an auditory animal.

The sense of touch is also very important to the pilot whale. This is substantiated by the captive's response to petting and caressing by the observer, as well as by its habitual rubbing on things. McBride and Kritzler (*loc. cit.*) present data which testify to the importance of the sense of touch in mother-infant relationships in the bottlenose. The manner in which the young dolphin plays about, rubbing itself on the heads and backs of adult animals, may be related to the way in which the pilot whale rubbed on the large sea turtles. This behavior commenced before the whale was permitted to mingle with the dolphins. Thus the turtles may have afforded a non-resistant subject for intimacy which the young whale would have reserved for others of its species had there been others present. Wild cetaceans rub themselves on various objects in response to irrita-

tion caused by ectoparasites. This is certainly not the case at Marine Studios, where such parasitism does not exist. It is obvious that most of the rubbing done by mature dolphins in the tank is performed only for the sensual pleasure involved. No other explanation for the eager acceptance of an especially designed back-scratcher comes to mind.

Vocalizations.—Of the several sorts of sounds produced by the pilot whale, two were obviously made by the lips of the blowhole. But it seems probable that the whistling or squealing, the grating snore, and the baby-like whining were not, since they could be generated under water without loss of air. Raven and Gregory (Amer. Mus. Novitates, no. 677: 1–16, 1933) have described the nasal anatomy of the sperm whale, *Physeter catodon*, in which the zenith of specialization of cetacean narial passages has been attained. In this account, the narial morphology of the cachalot is compared with that of the narwhal, *Monodon monoceros*, and of the pygmy sperm whale, *Kogia breviceps*. In *Monodon*, there are evaginations of the narial passages called spiracular sacs. Similar sacs are found in *Globicephala*. Raven and Gregory propose that these sacs serve in part to permit adjustment of air pressure when the whales are submerged. It is obvious that the sacs which are situated behind and below the pads which occlude the external bony nares serve as a bearing surface for the movement of these pads during respiratory exchange. It is proposed by the present writer that the sacs may also serve as receptacles for air forced from the lungs past the sound-producing pressure point. Kellogg (*loc. cit.*) reports the existence in cetaceans of inflatable evaginations of the eustachian tubes, which, it is here suggested, may serve the same purpose. These chambers could conceivably be deflated as the air is inhaled back below the source of vibrations, so that the sound might be repeated. All the while, the blowhole would be tightly closed, and the passage of air back and forth would be effected without loss to the exterior.

Play.—Play as an end in itself seems to be indispensable to the normal existence of dolphins. Play patterns, such as mock fighting, chasing one another, tormenting fishes and other small animals, may be linked with basic drives such as sex and hunger, but it is difficult to ascribe the incessant toying with inanimate objects with any of these. The potential for developing this sort of play seems to be no less strong in the pilot whale than in the more agile, smaller dolphins. Whether or not the behavior of wild pilot whales in their closely integrated herds is characterized by play of this sort is not known to the writer, but it is evident that if an individual is introduced into an environment in which it is continually being indulged in by other animals, a latent tendency will promptly find expression.

The manner in which the whale would amuse itself by thrusting a flipper through an inflated rubber ring, and carry it while swimming upside down at the surface, brings to the fore the fact that however well adapted the cetacean pectoral appendage is as a fin, there remain in it some vestiges of function as a foreleg. This was even more vividly demonstrated by the bottlenose dolphins in several situations. For example, as has been pointed out by McBride and Kritzler (*loc. cit.*), a mother dolphin attempted to raise the dead body of its infant from the bottom by grasping at it with her flippers. Courting dolphins

lie side by side stroking one anothers underside with their fins. A young female bottlenose carried innertubes on its flippers just as the pilot whale did, but elaborated on this by shaking the tube back and forth as she swam. A male, isolated from the others, was given short sticks to play with. It not only carried these in its mouth, but also with its flippers. Usually the latter was effected by its tucking a stick in the axilla, between the flipper and the body. On several occasions, however, it was seen to carry a stick held away from the body by pressing the palmar surface of its fins against the ends of the stick.

Energy versus growth.—One of the most interesting observations made on the young pilot whale was the enormous differential between the amount of food eaten and the extent to which it grew. During the nine-month period of observation, it consumed about seven tons of food. Most of this was squid. The digestive system of the pilot whale is so efficient that almost the only portions of a squid which are not eventually assimilated are the beak, the pen, and the melanin of the sepia. The whale was estimated to weigh not more than three hundred pounds when taken from the beach. At autopsy, it weighed five hundred five pounds. Thus, almost seventy times the amount of food which contributed to growth was expended as energy. The implications of this observation, especially as they relate to the utilization of the basic organic production of the sea, are by no means negligible. There is no reason, apparent to the writer, to suppose that the ratio of food actually contributing to growth to the total amount consumed is larger in wild cetaceans. In all probability it is smaller, because wild cetaceans must expend more energy in locomotion and, where the water is colder, lose more by convection. Thus, the amount of food that is required to produce a finback or a blue whale must be prodigious.

Systematics.—The whales with which this report is concerned have been erroneously referred to by the writer elsewhere as *Globicephala brachyptera* Cope. The writer is much indebted to Mr. Joseph C. Moore for calling his attention to the recent paper of Fraser (Atlantide Report No. 1, Sci. Res. Danish Exped. Coasts Trop. W. Afr., 49–60, 1950) in which the position of the black, broad snouted pilot whales has been clarified. According to Fraser, *G. brachyptera* as well as several other similar pilot whales are referable to *G. macrorhyncha* (Gray). The proportion of flipper length to that of the whole animal was the basis upon which the present writer referred his specimens to *G. brachyptera*. It was, on the average, about one-sixth. True's (Bull. U.S. Nat. Mus., no. 36, 1889) statement that *G. brachyptera* is wholly black, was, however, at variance with the situation in the whales reported on here, for all of them had a kedge-shaped grayish mark on the breast, the shank of the kedge passing posteriorly between the flippers to the region of the vent. This mark may have been present in the specimens examined by True while they were still fresh, but it may have darkened to a point where it was not noticed. The present writer has since collected the head of a half-grown male *G. macrorhyncha* at Beaufort, North Carolina. The fins of this specimen, which had the same ventral mark, were one-fifth the body length. It is probable that enough variation in flipper length occurs to make this character of doubtful value in identifying specimens.

SUMMARY

1. Observations on the stranding of forty-six pilot whales, *Globicephala macrorhyncha* (Gray), and on four of these in captivity are presented.

2. The distribution of the whales on the beach suggested that panic drove them ashore. Most of them lay below the low water mark and all but one were alive when discovered. They varied in size from seven and one-half to more than nineteen feet long. No female was more than fifteen feet long. The sexes were evenly divided. Mature males were distinguished by the nasal prominence overhanging the snout, a hump on the back, the large dorsal fin and flippers, and a dorsal crest on the caudal peduncle.

3. The larger specimens were drowned by the rising tide. Smaller ones were washed higher on the beach where they succumbed to heat stroke during the following ebb. Two small males and two females were moved to a tank at Marine Studios.

4. The compact grouping of the four captives, sleeping with their bodies generally touching, and their inoffensiveness added to evidence attesting to the dependence of the individual pilot whale upon the group for security. No interest was shown in the available food fishes. The two females and one male died within eight days.

5. At first the survivor ate only squid, breaking its fast on the ninth night after capture. Fed three times daily, it was trained at night to be hand fed from a fixed point at the tank's rim. Chronological adaptation to the feeding schedule and apparent recognition of the feeding attendant and his routine movements were quickly achieved. Vision was helpful, but the tactile and gustatory senses only seemed to be essential in identifying food. After several months it learned to eat preserved fish fed to the dolphins. It never ate any of the living fishes in the tank. The pilot whale seems to be more adapted to feeding on squid than on fish.

6. After changing from primarily nocturnal to diurnal activity, it began to develop play patterns. It amused itself by rubbing its body on turtles and by toying with various inanimate objects. In mock fights and games of chase with the dolphins it was always on the defensive.

7. During the mating season, it was so badly beaten by the male bottlenose dolphins that it stopped playing and reverted to nocturnal behavior. A tail wound caused it to swim by wagging this member from side to side.

8. It produced five sorts of sounds, three of which emanated from some point deeper than the lips of the blowhole. It is suggested that the spiracular sacs may be receptacles for air forced from the lungs when sounds are produced underwater.

9. The whale was killed by the dolphins. Fat at death, it is estimated to have gained about two hundred pounds in nine months. To do this it consumed almost seven tons of food.

Duke University Marine Laboratory, Beaufort, North Carolina. Received December 3, 1951.

LIFE HISTORY AND ECONOMIC STATUS OF THE MONGOOSE IN HAWAII

By Paul H. Baldwin, Charles W. Schwartz, and Elizabeth Reeder Schwartz

The Hawaiian Islands have borne the brunt of numerous accidental and intentional introductions of both plants and animals. Some have proved valuable, others undesirable. The mongoose was a deliberate importation, but the merit of this carnivore is a subject of controversy because opinions differ concerning its effectiveness as a destroyer of rodents, and much prejudice exists toward it because of its predation on domestic and wild birds.

The need for detailed information on the mongoose in Hawaii arises partly from its considerable economic importance and also from the lack of any comprehensive account of the behavior of this mammal in Hawaii, in the West Indies where it was also introduced, or in its native Asiatic range. In Hawaiian and West Indian literature, the mongoose has been the subject of frequent comment concerning the role it plays as a rodent catcher. Field observations, food analyses, feeding experiments, and ecological data of limited scope have been reported, but much more extensive information than is now available must be gathered before an overall judgment of the practical value of the mongoose can be made. Of theoretical interest, the mongoose in Hawaii exemplifies the integration of a small carnivore into an insular fauna which had lacked animals of this type. La Rivers' (1948) work is the first attempt to describe the ecological role of the mongoose in a natural Hawaiian plant-animal community.

The purpose of this study is to assemble information on the distribution, behavior, ecology, and human values of the mongoose in Hawaii. This report may be regarded as an outline suggesting fields for further exploration of the status of the mongoose in these islands. P. H. Baldwin obtained occasional records of the mongoose between 1938 and 1946 and collected mongooses from September 1948 to September 1949 on the Island of Hawaii for a study of the reproductive cyle of this animal with Dr. Oliver P. Pearson. The latter project received financial aid from the Committee on the Joseph Henry Fund of the National Academy of Sciences. Special thanks are due to Dr. and Mrs. Chester K. Wentworth for facilities made available for field work on the island of Hawaii. C. W. Schwartz and E. R. Schwartz observed the mongoose during a survey of the game birds on the major Hawaiian Islands from February 1946 through July 1947 as a Federal Aid—Wildlife Program of the Board of Commissioners of Agriculture and Forestry, Territory of Hawaii.

Mongooses were frequently noticed because of their diurnal habits; however, their tendency to retire to cover made extended observation difficult. Scats were collected and could easily be distinguished among those of the few mammalian species in Hawaii. The animals were trapped with number "0" steel traps baited with cooked meat (hotel scraps) suspended over the traps; results were best when traps were partially concealed with leaves. Feral cats frequently interfered with trap sets, and rats were caught in considerable numbers. A more

selective method of trapping mongooses was with sheet metal, drop-door live traps. Hardware cloth of ½-inch mesh was unsatisfactory as a material for live traps, since mongooses would chew a hole in it large enough to escape. Two hundred and twenty-one individuals were trapped over the year 1948–1949, and twenty-three of these were kept under observation in cages for varying periods of time. Twelve marked individuals were released, and three were recaptured. Live mongooses were handled conveniently by urging them into narrow cones made from chicken wire of one-inch mesh.

CLASSIFICATION

The mongoose in Hawaii corresponds most closely in measurements and description to *Herpestes auropunctatus auropunctatus* (Hodgson), and belongs to a genus of carnivores which has a widespread native distribution in southern Asia, Africa, southern Europe, and the East Indies. For the latest classification and statement of ranges of the species and subspecies of *Herpestes* see Ellerman and Morrison-Scott (1951). *H. auropunctatus* has been given such vernacular names as the gold-spotted mongoose (Jerdon, 1874: 136), the gold-speckled mongoose (Sterndale, 1884: 225), and the small Indian mongoose (Blanford, 1888–91: 121). None of these names has been adopted in Hawaii, where this weasel-like creature is known simply as the mongoose (plural, mongooses), a derivative of *mungus* from the Sanskritic Marathi language of western India. The full species is often called "Javan mongoose" in recent publications, but that name is now restricted to the species which occurs in Java, *H. javanicus*, (Ellerman and Morrison-Scott, 1951). Other names used in local literature for the mongoose in Hawaii include *H. birmanicus*, *H. mungo*, *H. griseus*, and *H. edwardsi*. These all appear to be technical misnomers and probably refer to *H. auropunctatus*.

In the hope that it would control rat populations in the sugar cane fields of Hawaii, this mammal was introduced from Jamaica in the West Indies to Hawaii in 1883 (Doty, 1945: 83). Tracing the origin of the Hawaiian strain further, it is known that the first importation to Jamaica was made in 1872 with mongooses shipped from Calcutta (Espeut, 1882: 713). Additional importations from India were made within the next few years. The possibility cannot be ruled out that these mongooses were obtained from more than one locality, and it follows that in Jamaica, and therefore in Hawaii, the mongoose may represent a mixture of at least two populations. Measurements of skulls of the mongoose in Hawaii (Baldwin, MS) appear to be somewhat larger than those typical of *auropunctatus* given by Pocock (1941: 33).

HABITAT IN HAWAII

Forest, grassland, desert scrub, seacoast, cultivated tracts such as sugar cane, pineapple, and coffee plantations, and settled suburban areas are all occupied by mongooses in Hawaii. Topographic conditions of many types support mongoose habitat. Even such inhospitable terrain as steep, wet slopes and rocky cliffs are visited by these small, agile animals, and burrows which were dug in

the high, muddy cliffs of windward Molokai by Hawaiian dark-rumped petrels (*Pterodroma phaeopygia sandwichensis*) have been appropriated by mongooses (Bryan, 1908: 141).

One feature essential to good mongoose habitat is the presence of ready-made retreats for shelter. Cracks and blisters in smooth lava, interstices between the boulders and clinkers on rough lava, tangled underbrush, root masses, logs, brushy litter, heavy grass, and chinks in stone walls provide passageways and retreats in which mongooses spend much time. A second essential feature is an abundance of food, although specific kinds of food may vary widely. The amount and type of vegetation may differ radically and seem of less direct importance in determining the suitability of a particular habitat than shelter and food.

The best habitat seems to be in the lowlands below 2000 feet elevation. Favored areas have a warm humid climate, mixed natural vegetation, and the diversity of cover and substrate afforded by clearings, rock fences, and paths which go with small-scale country farming. The humid, warm coastal forest in the Puna District of windward Hawaii harbors the heaviest mongoose population encountered in the trapping work; however, high populations also live in some portions of the Kau and Kona districts of this island where cactus and shrub-covered lava fields occur under arid conditions.

The seacoast is frequented where strand vegetation affords shelter, and littoral marine life may be taken as food. Mongooses forage at brackish tidal flats, on rocks exposed by receding tides, and on the beaches, while at other times they are in their rocky retreats in the lava and among clumps of cactus beyond the shore. At Pearl Harbor, Oahu, mongooses inhabit a small peninsula which juts into the estuary where they subsist in part on littoral animals and other available foods (La Rivers, 1948).

Small to moderate populations occur at elevations from 2000 to 4000 feet in mesophytic vegetation. Here again, mixed vegetation interspersed with clearings is preferred. Picnic areas, camp sites, and ranching establishments attract mongooses. Rarely are the animals found in the interior of virgin forests, as at Kipahulu Valley, Maui, where moss on the trees is perpetually wet and rainfall reaches 300 inches annually. Ash-covered lavas with shrubs and sparse forest around 3500 feet elevation on Kilauea Volcano, Hawaii, support very low mongoose populations.

NUMBERS AND SEX RATIO

Mongooses are abundant in many localities below 2000 feet elevation and generally less common above 2000 feet, although concentrations may occur in favorable places as high as 4000 feet. No census work was done to put population estimates on a numerical basis, but certain trapping records may afford some idea of the large numbers near Kapoho in the Puna forests of Hawaii just above sea level. On February 21 and 22, trapping was done with 24 trap-sets one-tenth mile apart which were left out for 24 hours and re-set twice during that period; the catch was 25 mongooses (20 males, 5 females). On March 10 and 11, precisely the same area was trapped with a slightly larger number of trap-sets

one-tenth mile apart which were left out for 30 hours and re-set three times during the period; the catch was 41 mongooses (37 males, 4 females). Similar trapping results were obtained in the dry cactus and shrub-covered lava fields of Punaluu, Hawaii, where the population was also quite large. Minimal populations were at places where a line of 10 to 12 trap-sets tended for a week would catch perhaps one or two animals, as in the sparsely forested areas of ash-covered lava south of Kilauea Crater, Hawaii, at 3500 feet.

The large excess of males caught in the traps at Puna is perhaps to be explained on a behavioral basis as the result of greater boldness and a tendency by males to forage aggressively, rather than as a true sex ratio of the population. When populations are very large, the traps conceivably may fill up with males before the females get to them in numbers; however, the situation at Puna may not be adequately accounted for by this, because elsewhere females were caught in nearly as large numbers as males, despite fairly large populations. The sex ratio for 225 mongooses, including the Puna catches, was 190 males to 100 females. Collectors of *H. smithi* in Ceylon may have had experiences similar to ours, for Phillips (1935: 189) says, "The male . . . is apparently very much more numerous. Of eleven specimens examined only two have been females."

Too few pregnant females with sex-differentiated fetuses were obtained by us to permit generalizations on the fetal sex ratio.

DESCRIPTION

The mongoose has a slender, lengthy body and short legs. An ample tail nearly doubles the length of the animal. The neck is long, and the head is narrow with a low cranium. The face is long, the nose is high and drawn to a point, and the ears are short and rounded. The weasel-like build of the mongoose equips it well for a life in crevices, brush, and burrows (Pl. I).

The agouti pelage is of a medium shade and has a yellowish cast. Broad, alternate rings of yellow and dark pigment in the guard hairs impart a grizzled effect to the coat. There is some variation in lightness or darkness of the overall tone of color. Infrequently a decidedly light individual was found, but never a markedly dark one and never a reddish one (other subspecies may be reddish). Pocock (1941: 30) attributes individual differences in coat in *auropunctatus* largely to seasonal variation. In the present study it was found that well-fed individuals living free at the field quarters at Kilauea, Hawaii (4025 feet elevation), in summer developed exceptionally fine coats in contrast to many wild animals caught at the same time in the lowlands which seemed to have thinner or more worn coats. Seasonal variations in coat color were not recognized by us in the field. The outer hair of the mongoose is moderately coarse over the entire body. The numerous guard hairs are about 20 mm. long. The underhairs are sufficiently sparse to suggest that the animal could not survive a climate of rigorous cold.

Almost all the trapped animals were skinned, and at no time of the year was any discoloration noticed on the under side of the skin, such as is seen in some other mammals during molt, for example in rodents. It appears that molt may

not be localized, but may proceed simultaneously and gradually all over. In two individuals, patches of approximately three square inches were depilated with the barium sulfide mixture of Pitesky and Last (1948). On May 2, hair was removed from the middle of the back of a female which was judged to be well into the third year of life by a method of estimating age based on tooth wear, suture closure as seen later in the prepared skull, and reproductive events explained in another paper (Pearson and Baldwin, MS). Twelve days later hair had started to grow uniformly over the patch. A male of about one and three-fourths years was depilated in the pelvic region on April 26. This individual was liberated and

PLATE I

Mongoose (*Herpestes auropunctatus auropunctatus*), Wailupe, Oahu, 25 feet elevation, June, 1945. Photograph by John H. Gerard

recaptured three and one-half months later (identified by clipped ear); the hair of the pelvic region was fully grown in and appeared normal. Probably regrowth of hair under these circumstances is not wholly comparable to natural molt, but these data show that hair may grow in *en masse* following depilation and that incoming hair completes its growth in less than three and one-half months.

The long tail is a conspicuous feature of the mongoose. It may be used aggressively to bluff an enemy by erecting the hairs to increase the diameter of the tail enormously, as a balancing aid in standing up and in maneuvering among rocks, and in reducing the rate of heat loss in sleep which might be important in view of the sparse undercoat of fur.

The feet are plantigrade, narrow, and elongate. The five claws are stout,

slightly decurved, and not at all retractile. Claws grow continuously, but wear down at the tips; captive mongooses developed long claws.

The skin is relatively unpigmented, hence light and pinkish, except at the nose and variably on genital areas where it is nearly black. In some individuals the black of the nose spreads over the forepart of the face. The eyes have a pale, yellow-green iris slotted by a horizontal pupil. Claws and soles are pale tan.

The teeth are primitive in the retention of all four premolars and two molars, whereas most modern carnivores have lost one or more molars or premolars from each jaw. In the mongoose the shape of the teeth is suited to a diversified but primarily carnivorous diet. Distinct carnassial teeth are present which are useful in shearing flesh and bones. The premolars are compressed, with the cusps aligned in a single row. Crushing surface is moderately well developed in the molars. The canine teeth are long, slender, and sharp, and the incisors form an effective cutting edge. The majority or even all of the teeth of individuals in their probable fourth or fifth year of life may be excessively worn down, virtually to the rims of their bony sockets. The jaws are relatively long to accommodate the full complement of teeth.

Both sexes of mongooses possess a pair of anal glands which open into the anal pouch. The glands may reach the size of a large pea and become filled with a cream-colored, cheesy substance. When pressed out, this secretion is not noticeably odorous; however, it was frequently noticed that adult male mongooses had a rank odor about them, especially when they were removed from the live traps. Possibly the secretion of the anal glands becomes odorous under certain circumstances, or perhaps the scent of the males is produced in some other less conspicuous dermal scent glands. Another species of mongoose in Asia, *H. urva*, is said to have anal glands the size of a cherry from which foetid fluid may be squirted with force (Pocock, 1941: 56; Brownlow, 1939), and *H. vitticollis* also apparently produces a musky secretion from the anal glands (Pocock, 1941: 50). The female *auropunctatus* possesses three pairs of mammary glands with the anterior pair smallest but fully functional, although several authors (Jerdon, 1874: 132; Sterndale, 1884: 223; Pocock, 1941: 5) state that only four mammae are present in *Herpestes*.

The body temperature of captive mongooses in daytime was taken rectally with a clinical thermometer, while the animals were held in a wire cone. It is possible that the effects of handling the animals caused some rise in temperature at the time the readings were made. Four adult individuals (three non-pregnant females and one male) were used for measurements in Table 1.

The range of temperatures for typically active mongooses in captivity during mid-morning, whose cages had not been touched by the sun, was from 98.4° to 102.1°F. The latter temperature was recorded in an individual which had not had food that day. It seemed as if temperatures were usually between 101° and 103° in the animals under these shade conditions. The temperature range of animals partially or wholly in the sun in the afternoon was from 102.2° to 104.9°F. Temperatures above 103° were reached when the sun was fully on the cage and the animals were wholly exposed to it. At 104.9°, female 582 lay stretched out

in a relaxed state, but was not panting, though occasionally mongooses held the mouth slightly open when overheated. In a state of extreme excitement and agitation, body temperature rose to 105.3° in female 710, even though the animal had been in the shade and without food since the preceding day. In all the measurements made, a total variation of 6.9° was noted. This suggests that body temperatures of the mongoose may fluctuate rather readily.

Male mongooses are almost half again as heavy as females. The weight ratio of adult males to adult females of *auropunctatus* in Hawaii (males, 1–2.8 lbs.; females, .7–1.35 lbs.) is similar to weight ratios of the two sexes in several larger species of *Herpestes*, including *H. flavidens* (= *fuscus*), *smithi*, and *vitticollis*, for which weights are given by Phillips (1935) and Pocock (1941). Among the latter the males range roughly from three to seven pounds, and in each case appear to be very nearly twice as heavy as the females.

TABLE 1.—*Temperatures of mongooses*

CONDITIONS	TIME	DATE	SPECIMEN	TEMPERATURE
Cage in shade all morning.....	10:40 A.M.	April 20	Female 603	98.4°F.
Cage in shade all morning.....	10:50 A.M.	April 20	Female 582	101.6°
Cage in shade all morning; air temperature 68°F; no food eaten that day.....	11:00 A.M.	July 9	Female 582	102.1°
Cage in shade at time of reading.	4.00 P.M.	April 19	Female 582	102.2°
Cage in sun.....	2:45 P.M.	April 19	Female 582	102.2°
Cage in sun.....	4:05 P.M.	April 26	Female 582	102.5°
Cage in sun.....	4:50 P.M.	April 20	Male 583	103.8°
Cage in sun.....	2:45 P.M.	April 19	Female 603	103.8°
Cage in sun.....	1:45 P.M.	April 20	Female 582	104.9°
Cage in shade all morning; air temperature 69°; no food eaten; animal excited.....	11:30 A.M.	July 9	Female 710	105.3°

In measurements of length, male mongooses exceed females (males, 516–659 mm.; females, 475–585 mm.). About two per cent of the animals caught were bob-tailed and not used in these measurements.

Specimens obtained in the present study were deposited as follows: Museum of Vertebrate Zoology, Berkeley, California, 7 skins, 211 skulls; Division of Zoology, University of California, Davis, California, 2 skins, 2 skulls.

DISTRIBUTION IN THE HAWAIIAN ISLANDS

At least four discrete populations of the mongoose occur in the Hawaiian Islands. These are on the islands of Molokai, Oahu, Maui, and Hawaii where a total of approximately 4500 square miles of range is occupied. Mongooses live from sea level to approximately the highest elevations on Molokai (4970 feet), Oahu (4025 feet), and Maui (10,025 feet). On Hawaii, the range extends from sea level to the upper limit of vegetation near 10,000 feet and excludes only the barren summits of Mauna Loa and Mauna Kea which rise to 13,680 and 13,784

feet, respectively. The highest altitudinal record available for *auropunctatus* in Asia is 7000 feet in Nepal (Pocock, 1941: 30). In Hawaii, the species is absent from Kauai, Lanai, Niihau, and Kahoolawe, presumably because it has never been introduced onto these islands.

Suitability of the Hawaiian climate.—The main islands of Hawaii, in their latitudinal position between 19 and 22 degrees N, are characterized by a moderately warm, oceanic, subtropical climate in which there is relatively more variation in rainfall than in temperature. Local differences in altitude, exposure to oceanic winds, and topography create a broad span of climatic variations both in temperature and in rainfall. Areas inhabited by the mongoose embrace climatic conditions grading from subtropical at sea level to those of frequent freezing temperatures at night at the highest occupied elevation. Annual rainfall varies from less than ten inches on the driest leeward coasts (generally western and southern) to 450 inches or more in windward regions (usually northern and eastern). An adult mongoose was seen deep in the virgin forest of Kipahulu Valley, Maui, at 6000 feet elevation where the yearly rainfall may reach well over 300 inches.

The Asiatic range of *auropunctatus* falls between the approximate limits of 20 to 35 degrees N latitude. Most of the southern half of the range lies in a belt of the humid tropics with a savanna climate of wet and dry seasons. The eastern portion of the range lies in a region of tropical monsoon climate. The northern half of the native range falls in a belt of humid subtropical climate with dry winters. Rainfall is generally more variable than temperature in these climates (see Trewartha, 1943).

The climate of Hawaii resembles that of much of the native home of *auropunctatus* in respect to the ranges of temperature and rainfall. It is probable, however, that the extremes of climate occurring in insular Hawaii are less severe than extremes occurring in continental India. In Hawaii the mongoose finds a climatic environment well suited to its requirements.

GENERAL HABITS

The mongoose is terrestrial and diurnal. It is probably active to a small degree in the dark, but nothing appears to be known about the extent or nature of any nocturnal activity in which it may occasionally engage. With captive animals the entire night as well as parts of the lay would be spent in sleeping. Activity usually commenced soon after daybreak. After eating a copious meal the mongooses generally curled up to sleep immediately. A curious attitude was often assumed for sleep in which the head would be thrust under the chest in an upside-down position with forepaws extended and tail either straight behind or flanking the body.

We found the mongoose an aggressive little carnivore, variously bold and inquisitive or retiring and secretive. Its wariness is plainly seen in its manner of keeping to cover and many hesitations in exploring new territory. Great hesitancy was seen in a female which was highly suspicious of a trap-set; she was apparently aware of the food used as bait, yet would not approach to take it.

Boldness was seen at another time when a male walked rapidly to a newly-placed trap, reached for the bait without caution, and was caught. Judging from trapping results the females are generally more wary. When a mongoose has just sunk its teeth into a hen or other highly desired morsel of food it may become momentarily oblivious to its environment and approaching danger.

A mongoose is a vicious adversary, as it will fight doggedly. In a defensive pose the animal will hunch up with hairs of back and tail erected and will strike out and withdraw much in the manner of a snake. When harried by a dog, mongooses were seen to face the larger animal and force it to keep its distance by nipping the nose. When retreating, those seen never backed up, but invariably turned tail and dashed, even if brushy shelter were a few steps behind. The mongoose does not seem to have the ability to use its bushy tail artfully to distract a pursuing animal.

In walking, the tail is held straight to the rear, and the animal glides along smoothly and swiftly with body low. It can dodge among grass clumps, skillfully reverse its direction, and elude a human pursuer. It can leap: a captive individual about one and one-half months in age persistently tried to jump into a cubby hole about two feet above the floor, and after repeated attempts managed to get into it by leaping to a nearby box and then into the nook. Mongooses hunted geckos, *Hemidactylus garnoti*, along the wall of a building and were able to reach or jump to a height of two feet to obtain them (La Rivers, 1948: 96). Tree climbing is seen occasionally. One individual was seen climbing over the wet moss on the trunk of an ohia lehua tree (*Metrosideros collina*) in the cloud forest of Kipahulu Valley at 6000 feet on Maui. Once a mongoose was noticed descending a tree. We never had an opportunity to watch a mongoose swim, but La Rivers (1948: 94) saw a mongoose partially enter the water, forefeet submerged to one inch, to catch a crab (*Podophthalmus vigil*).

Mongooses sit up on their haunches to peer around (see photograph in Walker, 1948: 81). The small eyes are set in such a position that they can look both upward and to the side without tilting of the head. One male about two years old was blind in one eye; no other individuals with impaired vision were found. The sense of smell is probably acute, since a large part of its food is undoubtedly located by this means. No evidence was obtained to indicate whether or not the sense of hearing is highly developed; however, the pinna is small. This may be an adaptation to life in burrows rather than an indication of poor hearing, since other fossorial adaptations are present, such as hairs directed backward to cover the meatus and skin flaps within the pinna which help to close the aperture when the ear is laid back.

A variety of sounds are made: young pups utter faint, high-pitched sounds; adults engaged in undetermined activity occasionally give forth soft sounds which reveal their presence in the bushes; growls and snarls are given vigorously when the animals are confronted by enemies; a sharp spitting sound is made as a gesture of threatening; and a piercing "chack" is uttered as it lashes out with its head at an aggressor. Prater (1936: 211) says newborn *auropunctatus* purr like a cat when they suckle and that the adult female may purr when given a drink

of milk. Our captive mongooses never were heard to make any sound that could be compared with the purring of a cat.

The mongoose is usually described as semi-fossorial. All subspecies of *H. auropunctatus* are said to occupy burrows, but some, as *H. a. pallipes*, are thought to dig their own (Pocock, 1941: 34), while others typically use pre-existing crannies and holes. This may well depend on the character of the terrain. In Hawaii, *auropunctatus* ordinarily has access to crevices in lava rocks or spaces around roots and logs. We did not come across burrows actually dug by mongooses, except that den entrances may have been altered somewhat where lava was more or less overlaid with soil, as at Kipuka Puaulu, near Kilauea, Hawaii. Prater (1936: 211) believed *auropunctatus* in India to live and breed in holes apparently dug by itself. We noted that much digging and scratching is done at soil under and around carcasses. Ghost crabs (*Ocypode ceratophthalma*) are dug from their burrows in sand by mongooses at Pearl Harbor (La Rivers, 1948: 94).

Recognition signs of mongooses in the field are provided by footprints in dust, scats along trails, hairs, odor, remains of objects eaten, diggings and dens, and sight and sound of the animals themselves. Prater (1936: 211) writes that in India, "Its presence can usually be detected by worn tracks it leaves along hedges."

Much is yet to be learned concerning the social habits of mongooses. Indications were seen that small groups of individuals move together into new territory. For example, it was quite certain that mongooses were absent from one farm at 3850 feet on Hawaii for about two months; then, one day in March, chickens were found killed, and mongoose traps were immediately set out. In two days, three mongooses were caught, one adult male and two females. The age of the male was not determined, but one female was immature, and the other was an adult of about 13 months. That mongooses are capable of cooperative effort in hunting is shown in La Rivers' (1948: 93) description of two individuals working together in seeking shore-crabs (*Metapograpsus messor*). One mongoose turned over stones and the other pounced upon the crab flushed from underneath, whereupon the predators both consumed parts of the crab and proceeded to catch more. We were informed by H. Shipman that the Hawaiian goose (*Branta sandvicensis*) is fully capable of defending its nest and young from a single mongoose, but that two or more mongooses can distract the adult goose sufficiently that the young can be obtained by the predators.

The matter of how widely and when mongooses move around is not understood. Do individuals tend to remain in one place or do they wander? In the rather unfavorable habitat of a farming area surrounded by wet forest with a rainfall of 120 inches per year at 3800 feet elevation on Hawaii, individual mongooses, pairs, or families would appear at irregular intervals of perhaps several months to become a temporary nuisance at chicken coops. However, sedentariness was seen at our field station at Kilauea, Hawaii, 4025 feet elevation, where several marked adult males remained in the vicinity for about six months. Some of these individuals were live-trapped and released several times. In the latter case,

scraps of meat remaining from skinning work were thrown out often, and this supply of food may have held the mongooses to the vicinity.

We have no evidence that mongooses establish hunting domains to keep out other mongooses. Where food is abundant and shelter adequate, large numbers may occur. Adult males (up to three individuals) kept together in small cages never seriously fought, though they bickered occasionally. In the wild, the animals congregate at carcasses. Thus, it seems likely that there may be relatively little hostility or tendency to drive each other from local food resources; however, further observations on this matter are badly needed.

REPRODUCTION

A detailed account of reproduction of the mongoose in Hawaii is given by Pearson and Baldwin (MS); here some major facts are mentioned to complete the general picture of the life history of this animal.

Scattered observations in Asia (St. John, 1891; Prater, 1936: 211) indicate that *H. auropunctatus* has a breeding season extending at least from late February into July, that gestation is about seven weeks, two or three pups may be born, and more than one litter may be produced in a single breeding season.

Field data from mongooses collected in Hawaii between September 1948 and September 1949 include the macroscopic appearance of the reproductive tracts. Swollen uteri indicated that the reproductive season was under way in February, and lactation showed that it continued through September. Subsequent laboratory work by Pearson (Pearson and Baldwin, MS) showed that one early pregnant female was taken in late February, two in March, and three in April. A visibly late pregnant female was obtained on April 10, and lactating parous females were first caught in mid-April. Two of the April pregnancies would have gone into May if allowed to continue. The earliest female with a litter, seen abroad in 1949, we learned, was observed in Puna, Hawaii, by E. S. English (personal communication) on April 13, when he saw a female followed by a small pup. Pregnant females were not taken in May nor in the first week of June. About June 9, two early pregnant females were caught, then more pregnancies were encountered in late June and July. At least one of the July pregnancies would have gone into August. Nearly all adult females caught in August and September were post-partem and lactating. All females obtained from October to January, inclusive, were in non-breeding condition. The distribution of pregnancies indicates the occurrence of two reproductive peaks, one between February and April and the other between May and July.

In Hawaii the number of fetuses ranged from two to four, in the case of nine pregnant females with fetuses from 5 to 50 mm. in size (crown-rump length), with the average at 2.7 fetuses per female. In 35 parous females, the number of uterine scars ranged from one to four (or possibly five) with the average at 2.4 and the mode at 2 (17 females). The number of uterine scars probably corresponds to the number of fetuses at the last pregnancy; yet this method of determining the probable fetal count is somewhat inaccurate because of difficulty in interpreting the scars. In 5 of the 35 parous females in which scars were present, it was not certain whether there were 2 or 3, 4 or 5, etc., scars.

Adult males collected throughout the year showed enlarged testes and the presence of sperm at all times.

FOODS

The enumeration below of specific foods taken by the mongoose in Hawaii includes the results of our[1] analysis of 86 mongoose scats from rocky, open-grass pastures from 2000 to 4500 feet elevation on the leeward side of Hawaii (Table 2); records of mongoose foods obtained while handling animals which had been

TABLE 2.—*Foods of the mongoose in Hawaii determined from an analysis of 86 scats*

FOOD	AGGREGATE PER CENT OF TOTAL VOLUME OF FOOD REMAINS	NUMBER OF OCCURRENCES
Mammals	39.6	
Mus musculus, hair, bones	36.4	29
Rattus sp., hair	3.2	2
Herpestes sp., hair	T	2
Unidentified hair	T	1
Birds	4.1	
Streptopelia c. chinensis, breast and neck feathers	4.0	5
Unidentified feathers	0.1	2
Geopelia s. striata, neck feathers	T	1
Phasianus t. torquatus, feathers of poult	T	1
Insects	27.0	
Blattidae, fragments	13.9	15
Unidentified fragments	9.6	21
Coleoptera, fragments, including *Onthophagus insensus*	2.1	8
Lepidoptera, adults, larvae, including *Agrotis ypsilon*	1.4	9
Plants	29.3	
Opuntia megacantha, seeds	25.7	12
Sporobolus capensis, seeds	3.5	4
Solanum nodiflorum, seeds, fruit	0.1	1
Rubus rosaefolius, seeds	T	1
Unidentified seeds	T	3

trapped from a wide variety of habitats between sea level and 7000 feet on southeastern Hawaii, and field observations on mongoose feeding habits on all islands.[2] Published records cited include studies by Pemberton[3] (1925: 42), who examined 356 mongoose scats from sugar cane fields at approximately 1000 feet elevation on the windward side of Hawaii; Swezey[4] (Pemberton, 1933: 13), who made a "number of examinations of mongoose excrement" from a variety of mountain and valley habitats on Oahu; La Rivers[5] (1948), who analyzed 23 stomachs of animals at Pearl Harbor; and occasional references by other authors.

Superscript numbers below refer to sources of information with corresponding numbers listed in the paragraph above.

Vertebrate foods.—Mammals: *Mus musculus*[1]; undoubtedly all four forms of *Rattus* (*cf.* page 352) occurring in Hawaii[1, 2, 3, 4]; *Herpestes*, cannibalism on trapped individuals and carrion[1, 2]; pig, carrion[2]; goat, carrion[2]. In regard to the quantity of rodents eaten, Pemberton's (1925: 42) study of mongoose foods in the sugar cane fields gave high figures for rodents: in 88.4 per cent of the scats which contained parts (bones, teeth, hair) of rodents, 52.2 per cent contained nothing but rodent remains and 36.2 per cent comprised a mixture of insect and rodent parts. Of scats from the open pastures (Table 2), rodent remains occurred in 39.6 per cent. In this habitat mice were an important food, constituting 36.4 per cent of the aggregate volume of food remains; rats were insignificant, as they comprised only 3.2 per cent. This probably reflects the relative abundance of the two kinds of rodents in the pastures. Our observations indicate that rodents are not necessarily taken in large quantities by mongooses, despite their probable preference for them. Local limitation of supply and inaccessibility of noctural rodents to a diurnal predator may be factors preventing full use of rodent foods.

Observations made on our captive adult mongooses may suggest something as to food preferences. When recently-killed, small birds were held against the wire of the cage, the mongooses always became excitedly engrossed with trying to reach them through the screen. When small rats were similarly placed or even introduced alive into the cage, the reaction was as often as not one of apathetic disinterest. Sometimes many minutes would elapse before the mongoose would attack the living rodent, especially if the mongoose were worried about the presence of a person. It usually made the kill by seizing the rat across the top of the head and crushing the cranium. Doty (1945: 83) found that two wild mongooses kept in cages were invariably eager to get at a rat and would seize it before it could be hurriedly thrust through the opening. The most agile rat seemingly had no chance even to put up a fight; the mongoose always grabbed the rat by the back of the neck, growled, and crushed the bones audibly. In a few minutes the mongoose would eat the rat, leisurely beginning at the head and leaving only such scraps as a part of the tail, a foot, or a small strip of skin with hair.

Carrion was taken even in the form of highly putrified or desiccated meat. Large carcasses would be reduced slowly. Cannibalism was seen in one instance when a female caught in a steel trap was killed and partly consumed by a male; in other instances injured animals with raw wounds were victimized when confined with other mongooses; skinned mongoose carcasses were eaten avidly by the captives. Doty (1945: 85) reported that when confined together mongooses will kill and eat the weaker members of the group, but this did not happen in our experience when in several instances three or four healthy males or females were confined in small cages together for many days.

Birds: *Pterodroma phaeopygia* (Hawaiian dark-rumped petrel) (Bryan, 1908; Henshaw, 1902); *Nycticorax nycticorax* (black-crowned night heron), carrion[5]; *Branta sandvicensis* (Hawaiian goose), goslings (hearsay); *Phasianus t. torquatus* (ring-necked pheasant), poult[1], adults, eggs[2]; *Lophortyx californica* (California quail) (Craddock, MS); *Pavo cristatus* (peafowl), eggs[2]; domestic poultry, adults, chicks, eggs[2]; *Pluvialis dominica* (golden plover), caged bird[2]; *Geopelia s. striata* (barred dove), adult[1, 5]; *Streptopelia c. chinensis* (lace-necked dove), adult[1, 2]; *Acridotheres tristis* (myna)[5]; *Carpodacus* (finch) or *Passer?* (sparrow)[5].

Birds are utilized to a limited degree undoubtedly because of the difficulty mongooses have in catching them. In our study of 86 scats, bird remains amounted to only 4.1 per cent of the food. Birds most susceptible to predation are those which spend considerable time on the ground. Birds up to the size of a hen are easily killed; apparently a small Hawaiian goose can stave off a mongoose by its defensive actions and formidable bill, though this may not always be the case. However, game birds are easily taken. Craddock (MS) tells of an attack of a mongoose upon the California quail. He saw a mongoose in a bush (*Styphelia*), and it happened that a pair of quail he flushed flew into the bush. He heard a noise issue from the bush; running over to it he flushed out both the quail and the mongoose. Evidence of the attack was a great number of fresh quail feathers inside the bush. Feathers from a

pheasant poult, a barred dove, and five separate occurrences of feathers from lace-necked doves in the scats (Table 2) indicate likely predation on these game species. On one occasion at 5500 feet on windward Hawaii, a lace-necked dove was shot and crippled. While still fluttering on the ground, it was seized by a mongoose and whisked away to a den in a nearby pile of rocks before we could retrieve it. At sea level on the leeward sides of Hawaii and Maui, freshly-killed and dissected barred doves, lace-necked doves, and pheasants were taken on six occasions from our camp by mongooses, all in plain sight of the observers. At another time, two carcasses of cock pheasants were found beneath overhanging rock ledges which marked the site of mongoose dens at 5500 feet elevation on leeward Hawaii; however, these could easily have been pheasants killed or crippled during the hunting season which just preceded these observations.

Much evidence is available that these mammals prey upon adults, chicks, and eggs of domestic poultry in Hawaii. The manner of feeding on eggs was witnessed by Walker (1948: 88). The mongoose first tried to bite through the shell, and if successful he lapped up the contents; if unsuccessful he would straddle the egg and pass it backward between his hind legs, this maneuver being repeated until the egg struck some object and broke. Another method is described by Pocock (1941: 60), who saw mongooses (*H. edwardsi*?) in the London Zoological Gardens grasp the egg in the embrace of the fore legs, lift it some inches by rearing on the hind legs, and smash one end of it by banging on the floor of the cage. At 4500 feet elevation on leeward Hawaii, a mongoose was suprised beside a wild pea fowl egg which it had just rolled from a nearby nest. The egg had been punctured on the side and most of its contents drained. Pheasant nests pilfered by this predator were occasionally seen, and cowboys have reported mongooses feeding on pheasant eggs.

Reptiles[5]: *Lepidodactylus lugubris* (mourning gecko); *Hemidactylus garnoti* (fox gecko); *Emoia cyanura* (azure-tailed skink). Reptiles are such a minor faunal element in Hawaii that their use is decidedly limited; however, they were said to be an important part of the mongoose's diet at Pearl Harbor (La Rivers, 1948: 96).

Amphibians[5]: *Bufo marinus* (tropical American toad); *Rana catesbiana* (bullfrog). Amphibians are poorly represented in species in Hawaii, but *Bufo marinus* is abundant in numbers. The records of occurrence for *Bufo* in mongoose stomachs are not proportionate to their abundance in their lowland habitat; this may be a result of the nocturnal habits of the toads. It has also been suggested that they are unacceptable to mongooses because of the abundant poison glands of the skin; however, the unpublished results of an experiment by the late Charles S. Judd in Honolulu, made available to us by the Board of Agriculture and Forestry, indicate otherwise. The experiment consisted of placing six mongooses in a large wooden box with six toads on May 1; no other food was supplied. On May 2, four toads had been eaten by the mongooses, and one mongoose was dead. (It was believed, however, that this animal did not die from poison but from internal injury received on being transferred from the mongoose trap to the box.) From May 2 to 4, the mongooses and two live toads were living together harmoniously in the box; on May 5, six toads were added, and on subsequent dates others were put in, making a total of twenty-one toads used in the experiment; from May 5 to 7, one toad a day was eaten by the mongooses. The experiment terminated on May 12, with only one live toad remaining in the box and with the mongooses alive, saucy, active, and in excellent health. In eleven days the five mongooses ate twenty toads with apparent relish and no ill effects.

Fishes[5]: *Mujil cephalus* (mullet); *Eleotris fusca* (sleeper); *Mollienisia latipinna* (top minnow). Fishes must be a rather sporadically taken food, and the fact that the majority of mongooses do not live where they have access to fish limits the occurrence of this food item in mongoose stomachs collected at large. La Rivers (1948: 95) found that mongooses could obtain stranded, live fishes from the shallow water of tide pools.

Invertebrate foods.—Insects: Blattidae (cockroaches)[1, 2]; *Periplaneta americana* (American cockroach)[5]; *Periplaneta*, 2 spp. (Perkins, 1913: ccxiv); *Leucophaea surinamensis* (probably *L. maderae* (Madera cockroach) (see Zimmerman, 1948: 93)[5]; *Diploptera dytiscoides* (cypress roach)[5]; *Tenodera angustipennis* (praying mantis)[5]; grasshoppers[4]; *Oxya chinensis*

(Chinese grasshopper)[4]; *Elimaea punctifera* (narrow-winged katydid)[5]; *Conocephalus saltator* (grasshopper)[4]; *Gryllidae* (crickets)[4] spp.; *Gryllotalpa africana* (African mole cricket) (Zimmerman, 1948: 127); *Acheta oceanica* (oceanic field cricket) (*ibid.*, p. 130); Lepidoptera (moths), adults and larvae[1]; *Agrotis ypsilon* (greasy cutworm)[1]; *Scotorythra* (geometer) sp., larvae[4]; Coleoptera (beetles)[1, 2], adults, larvae ?, pupae ?; *Gonocephalum seriatum* (darkling ground beetle)[4]; *Onthophagus insensus* (scarab beetle)[1]; *Adoretus sinicus* (Chinese rose beetle)[4]; *Polistes hebraeus*? (wasp)[4]; honey bee[4]; Diptera (flies), larvae[3].

Insects are an important constituent of the mongoose diet, having been reported by all who have studied mongoose food habits in Hawaii. In scats from open-pasture habitat (Table 2) insect remains comprised 27.0 per cent of the total volume, with cockroach parts alone representing 13.9 per cent. In the trapping work, cockroach parts were noted in almost all the scats seen and in stomachs opened from mongooses in the lowland cactus-shrub habitat at Punaluu, Hawaii. Pemberton (1925: 42) found insects alone in 11.5 per cent of droppings from sugar cane fields and insects in combination with other foods in a much higher percentage (36.2) of droppings; the insect parts were predominantly of roaches. An adult mongoose we captured within the city of Honolulu was found to have made a large meal of cockroaches, as the stomach was engorged with these insects; thus, the mongoose appears to be an important enemy of cockroaches. The field cricket *Gryllus* may form a large part of the food of the mongoose in the lowlands and lower mountain elevations (Perkins, 1913: ccxvii). Beetles, lepidopterous larvae, and other insects were occasionally recovered from food samples or scats. At goat carcasses visited by mongooses, the ground underneath would typically be scratched and pawed over thoroughly, perhaps in a search for carrion insects (adults, pupae, larvae) which accumulate in such situations. Large maggots may have been ingested incidental to carrion feeding in one instance, for numerous maggots were found dead but entire, having resisted digestion within their tough cuticles, in the lower part of the intestinal tract of a mongoose which had swallowed putrid meat. Doubtless the larvae of dipterous insects in the droppings of both feral and domestic sheep and feral goats prove attractive to mongooses as food at high elevations where plant growth is limited and rodents and birds scarce. La Rivers (1948: 98) reported that few insect remains were found in mongoose stomachs at Pearl Harbor.

Spiders: "spiders"[4].

Isopoda: *Ligyda* sp.[5].

Crabs[5]. *Metapograpsus messor* (shore crab); *Scylla serrata* (Samoan crab); *Podophthalmus vigil* (Hawaiian crab); *Ocypode ceratophthalma* (ghost crab).

Plant foods.—*Psidium guajava* (guava), seeds[2, 4]; *Opuntia megacantha* (prickly pear cactus), seeds[1]; *Rubus rosaefolius* (thimbleberry), seeds[1, 2]; *Vaccinium* sp., seeds[2]; *Solanum nodiflorum* (popolo), seeds and outer fruit coats[1]; *Momordica balsamina* (balsam apple) seeds and fleshy seed coating[2]; *Sporobolus capensis* (rattail grass), seeds[1]; "grass"[4].

Plant foods in mongoose stomachs and excreta are sufficiently frequent in occurrence and quantity to preclude accidental ingestion. In our analysis of scats (Table 2) plant foods amounted to 29.3 per cent of the total food remains, suggesting that fruits and seeds constitute a regular, if usually minor, part of the diet. The possibility that fruit seeds were ingested only with the crop or stomach contents of some avian prey seems unlikely because of the large amount of plant material and the small volume of bird remains. *Psidium* fruits litter the ground in many lowland thickets of this shrub; *Momordica* is a trailing vine of the lowlands, and the small squash-type fruits are easily obtained; *Opuntia* is a dominant cactus in some dry, lowland areas and drops fruit seasonally; *Rubus rosaefolius* is a low shrub common in forests of moderate elevation and climate on Hawaii and bears fruit abundantly for a long summer season; the shrub *Vaccinium* occurs up to nearly 10,000 feet on Hawaii and bears fruit over a large part of the year; *Solanum nodiflorum* provides small, juicy fruits seasonally at low and middle elevations. The occurrence of grass and grass seeds in the scats may be accidental, as these were most likely ingested along with other foods. However, plant foods may not always be taken, as Pemberton (1925: 42) detected no plant remains in 356 mongoose pellets from sugar cane fields at Honokaa, Hawaii; presumably fruits were

not available, and perhaps the mongooses ordinarily did not forage far enough to reach adjacent gullies where guava trees were apt to grow. This suggests an ability of mongooses to feed successfully on a limited variety of food types depending upon the local resources.

Other foods: In captivity the mongoose has been known to accept certain food items which have not been recorded as part of its diet in the wild; these include bananas, coconut meat, bread, centipedes, and earthworms. Baked or fried ham was the least readily accepted of the several kinds of cooked meats offered our captive animals. Doty (1945: 86) tried to induce captive mongooses to accept dry cereal foods, such as whole wheat, flaked wheat, rolled barley and rolled oats, and also sugar cane, but without success.

Comparison of mongoose foods in Hawaii and elsewhere.—Regarding the typical diet of Indian mongooses, Pocock (1941: 58) says that with few modifications due to differences of environment the habits of the several commoner species of *Herpestes* appear to be similar and resemble those of the stoats and weasels. They are mainly predatory, preying upon any mammals, birds, or reptiles they are capable of killing, upon the eggs of the last two classes and upon insects, scorpions, and other invertebrates; also, they will eat fruit or other vegetable substances to a small extent. In the West Indies, rats occur in small amounts in the diet of the mongoose, while ground-nesting birds, lizards, snakes, frogs, toads, and insects predominate (Myers, 1931). In an attempt to evaluate the food habits of the mongoose in Trinidad, Williams (1918) constructed the following "balance sheet" based on his food analysis of 166 stomachs collected throughout the year: "Credit: 28 rats, about 600 injurious insects, and 3 crabs. Debit: 26 birds, 17 lizards, 29 frogs and toads, 44 useful insects, and 44 spiders." Foods of no practical importance such as "half a dozen fruits, one feed of yam, a little coconut" were omitted from this tally.

The foods utilized in Hawaii by the mongoose appear to agree closely in character with foods used in its native range and in other areas where it has been introduced. In Hawaii it takes a great variety of foods, and the diets of individuals may vary widely in accordance with resources offered by the environment. Living terrestrial vertebrate animals of small size are the most eagerly taken food; invertebrate creatures such as large insects, spiders, and crabs make up a substantial portion of the diet; while carrion and small fruits contribute smaller amounts.

Comparison of mongoose foods with foods of other predators in Hawaii.—The food of the mongoose as a small predator may be compared with the foods of other predators in Hawaii. The feral cat is a carnivore somewhat similar to the mongoose, but considerably less numerous in the wild. Little information is available on the foods taken by the feral cat, although it is commonly regarded as a killer of rodents and birds. Overlap in diets may be largely prevented by the nocturnal habits and probably more arboreal hunting methods of the cat, as contrasted with the diurnal and terrestrial hunting of the mongoose. The feral dog is extremely scarce in Hawaii. It uses larger game, such as wild goats, sheep, and pigs. A band of roaming hunting dogs has been known to attempt an attack on man. No information is available as to the small species of mammals and birds which might be utilized by the feral dog. Feral pigs, which are also common predators and are widely distributed in the islands, feed to some extent upon grubs, carrion, and the eggs of ground-nesting birds. The prey species of rats would presumably overlap with those of the mongoose insofar as the rat is a predator at all. The Hawaiian owl (*Asio flammeus*) and the Hawaiian hawk (*Buteo solitarius*) take birds, insects, and rodents, but their populations are low, and the hawk is found only on the Island of Hawaii. Obviously each of these predators overlaps in its foods to a degree with the mongoose, yet none appears to be a real competitor of the mongoose. In Hawaii the mongoose finds an open food niche, a primary condition which has permitted the establishment and maintenance of large populations wherever this animal has been introduced in Hawaii.

PARASITES AND ENEMIES

The external parasites of the mongoose in Hawaii have been studied by Eskey (1934: 32–50), who obtained data on fleas from 1165 mongooses. Fleas

occurring uncommonly on mongooses, but much more frequently on rats and mice, were: *Xenopsylla cheopis*, the tropical rat flea (27 examples taken); *X. hawaiiensis* (39 taken); *Nosopsyllus fasciatus*, the European rat flea (rarely taken); and *Leptopsylla segnis* (rarely taken). For all these species the mongoose apparently is not a natural host, as indicated by the low infestations. Fairly large numbers of the tropical hen flea, *Echidnophaga gallinacea*, were recovered from mongooses. Such large numbers of *Ctenocephalides felis*, the cat flea, were found that Eskey concluded the mongoose must be one of their natural hosts. Only one example of *Pulex irritans*, the human flea, was taken. All specimens of mongooses we handled in the present trapping work were infested with fleas.

No intestinal parasites were noticed while eviscerating our specimens, although no special search for parasites was made. J. E. Alicata has informed us that the nematode *Trichinella spiralis* was found in 15 of 70 mongooses he examined on the Island of Hawaii and in two of 22 mongooses he trapped on Maui. Alicata and Breaks (1943) recorded the spirochaete *Leptospira* (organism of Weil's disease or infectious jaundice) in the kidneys of mongooses. They found that four of 12 mongooses examined from Oahu, 12 of 60 from Kohala, Hawaii, and six of 26 from Olaa, Hawaii, were infected. The relatively small number of leptospirae seen in the kidney tubules of the mongooses as compared with the much heavier infections seen in Norway rats suggested that the infection in mongooses may not be as chronic in form as it is in the rat (Alicata, 1944: 24). The Norway rat is the prime carrier of this infection, and the mongoose may contract the organism through its habit of rat predation. Mongooses would be most likely to carry the disease in areas where the Norway rats are most abundant, as in areas of high rainfall near human habitations on Hawaii (Alicata, 1944: 16, 20). One of our captive mongooses which died after a few weeks of captivity showed bloody urine; perhaps death was caused by a leptospiral infection, though an examination was not made.

Enemies of the mongoose are few in Hawaii; man, dog, and cat being the main ones. La Rivers (1948: 98) saw a half-grown mongoose that was killed and brought in by a tom cat. Dogs kill adult mongooses easily. It was pointed out by Judd (MS) that *Bufo marinus*, despite its poisonous skin glands, is not a decimating agency in the mongoose population, as the mongooses are unaffected by the poison when toads are eaten (*cf.* page 348).

COACTIONS OF THE MONGOOSE IN HAWAII AND ITS ECONOMIC STATUS

Many kinds of effects must be considered in judging the economic status of the mongoose. The approach followed here will be to assess the coactions of the mongoose with groups of animals of interest and use to man or harmful to man. We shall not attempt to translate the loss or gains in terms of dollars, but rather to expose the major kinds of biological consequences resulting from the presence of the mongoose, especially those which directly or indirectly have some relation to the interest of man.

A detailed study has not yet been made of the interactions between rodents and the mongoose in Hawaii. Since rodents are the principal vertebrate prey of

the mongoose, it may be assumed that the population of rodents is reduced to some extent by the predations of this abundant carnivore. It is a common belief expressed by Walker (1948: 82) and others for Hawaii and by Barbour (1930) for the West Indies that predation by the mongoose has caused certain species of rats to become arboreal nesters. For various reasons this seems unlikely. In Hawaii, the native Polynesian rat (*Rattus hawaiiensis*) and the Norway rat (*R. norvegicus*) are terrestrial nesters, while the black rat (*R. rattus rattus*) and the Alexandrine rat (*R. rattus alexandrinus*) nest above ground in trees, shrubs, or among rough lava rocks (Doty, 1945: 80). These habits persist in these species on islands both with and without the mongoose and elsewhere in the world where the exotic rats live (*cf.* Storer, 1948), indicating that tree nesting in Hawaii could hardly be a specialized adaptation to predation by the mongoose. Many of the so-called rat nests pointed out to us, especially on mongoose-free Kauai, proved to be the bulky nests of the ricebird (*Munia punctulata*), which is common in parts of the coastal areas of the island. Discussing the arboreal habit of rats in the West Indies, Myers (1931: 95) stated that the black rat (*Rattus rattus*), which was introduced into New Zealand in the early days of settlement, eventually became almost wholly arboreal following the later importation of the Norway rat (*R. norvegicus*). It seemed probable to him that the same thing happened in the West Indies and would have happened even without the intervention of the mongoose.

Originally, the mongoose was introduced into the West Indies from India in 1872 in an effort to control rat populations menacing sugar cane plantations. It is reported to have been successful in controlling some of the rats there (Doty, 1945: 83), but it also caused the reduction or extinction of certain ground-nesting birds and terrestrial reptiles (Barbour, 1930). However, in addition to the mongoose, extensive land-use changes in the West Indies, and predation by man and other animals, have been important factors related to the changes which occurred in the fauna of these islands.

Rat poisoning methods are now so efficient that they mask the effects of rodent reduction by the mongoose in Hawaiian sugar cane fields. It is generally conceded that before the days of pre-baiting techniques in rat poisoning the rat damage in sugar cane fields was less on islands having the mongoose than on Kauai, where it had never been introduced (Doty, 1945: 85). From the viewpoint of sugar cane agriculturists the mongoose does much more good than harm on plantations because it rids cane areas of many rats and insects (Doty, 1945: 83). The universal presence of rats on all islands is evidence that the rodent problem is still severe, however. The fact that the introduction of the mongoose onto Lanai, Kauai, and Niihau is not desired by plantation owners on those islands in itself shows that this predator is not accepted as a decisive factor in the control of rodents and that it is regarded as having disadvantages which may outweigh its benefits. Aside from the interests of the larger agricultural enterprises in Hawaii, rat and mouse reduction by the mongoose must be of considerable importance to farms and suburban areas.

The relations between game birds and the mongoose deserve study for practical

reasons. The mongoose is commonly claimed the limiting factor on ground-nesting birds in Hawaii. Our data show that some ground-nesting game birds are taken by this mammal, but it is probable that the amount of predation on game birds is not a *limiting* factor in their survival. Recent studies by Smith and Woodworth (1951) indicate that predation by the mongoose (and possibly feral cats) was responsible for the destruction of 35.9 per cent of 167 pheasant nests located on Hawaii and Maui. The destruction was greater in areas of sparse vegetation at lower elevations than in denser cover at higher altitudes where this predator was less abundant. In the range of the mongoose several ground-nesting bird species—the ring-necked pheasant, the green pheasant (*Phasianus v. versicolor*), the Japanese quail (*Coturnix coturnix japonica*), and the skylark (*Alauda arvensis*)—are able to maintain populations equal to or better than those on islands without the mongoose. One exception is the California quail on mongoose-free Niihau where populations are reported to exceed slightly those on any island with the mongoose (Fisher, 1951: 33, and letter). Yet it is still significant that we found densities up to 600 birds per square mile occurring in areas occupied by the mongoose (Schwartz and Schwartz, 1950: 30). It appears evident that climatic conditions and the quality and quantity of food, cover, and water exert a far greater influence on the success of certain ground-nesting birds, namely non-colonial forms, than does predation by the mongoose (Schwartz and Schwartz, 1949: 34; 1950: 26). A study of these ground-nesting birds shows that where the habitat is best suited to their requirements, conditions are not as favorable for the mongoose, and conversely, optimum environment for the mongoose is less suitable for ground-nesting birds.

The critical factor in the virtual extirpation of small sea birds, such as the Hawaiian dark-rumped petrel, from the islands inhabited by the mongoose has been accredited to predation by this species. Bryan (1908: 141) found evidence of predation on this petrel on Molokai where mongooses had invaded a nesting colony and were raising their own young in burrows made by the displaced birds. The Newell shearwater (*Puffinus newelli*) formerly nested in ground burrows on Maui; its only occurrence in recent years was reported on Kauai, however, by Pearsall (1947: 45) who found two adults with young. In connection with the survival of this species on mongoose-free Kauai, it is significant to report that we observed several breeding colonies of wedge-tailed shearwaters (*Puffinus pacificus cuneatus*) in 1946 and 1947 on this same island.

Sea birds of larger size can rear young, despite the presence of the mongoose. In January, 1947, red-footed boobies (*Sula sula rubripes*), apparently from the nearby islet of Moku Manu, attempted to establish a breeding ground on Mokapu Point, Oahu. During this colonization, these birds were subjected to violent disturbance by military personnel who used them for target practice. For obvious reasons, nest building, laying, and incubation, though attempted, were unsuccessful. With cessation of this destructive practice, approximately 450 pairs of birds took up residence in the same area and were uninterruptedly incubating their eggs and rearing their young when our last observations were made on June 21, 1947. Many of the nests were built on the ground, but most were from two to

ten feet off the ground in the shrub koa haole (*Leucaena glauca*). In this same area mongoose sign was evident though not common. An examination of six mongoose scats here showed only rodent and insect remains; no evidence of predation by the mongoose was found anywhere in this colony.

Accusations against the mongoose may be unduly severe regarding its ability to exterminate ground-nesting birds. The continuing presence of the various introduced game birds, the fact that the Hawaiian goose has survived for 68 years in the presence of the mongoose, that some sea birds are able to breed on mongoose-inhabited islands, and that the ground-nesting Hawaiian owl and skylark are still present on all the major islands shows that where other factors are at least partially favorable to these birds they can survive.

Aside from the reduction of rodent populations and predation on birds, large insects such as cockroaches are destroyed by mongooses. This mammal performs good service in helping to reduce carrion, thus perhaps reducing such insect populations as flies breeding in carrion.

The mongoose is notorious in raiding poultry pens, taking both birds and eggs. Tamed mongooses apparently cannot be broken of this habit. Undoubtedly this single behavior trait has brought it into great disrepute in Hawaii.

Mongooses are commonly kept as pest-catchers in India, and probably *H. auropunctatus* is one of the species used, although the disposition of this species may make it less amenable to taming than certain others, such as *H. edwardsi*. In Hawaii the mongoose is not regarded as a household adjunct, though it does afford some amusement as a pet when very young and tamed.

The mongoose is an agent in spreading such lowland fruits as guava and balsam apple, thus helping (in the latter case) to provide food for game birds, for the balsam apple is an important food of the lace-necked dove (Schwartz and Schwartz, 1951: 97).

We have been told by local residents that mongoose meat is eaten for supposed medicinal qualities by some Chinese in Hawaii. The danger of such a practice is evident from the occurrence of *Trichinella* and *Leptospira* in the mongoose in Hawaii, as previously discussed.

The official policy toward the mongoose in Hawaii is revealed by the existence of a law prohibiting its being transported, kept as a pet, or given shelter or succour, except for scientific purposes on permit; moreover, there was a brief-lived bounty on the species in the Kona District of Hawaii some years ago.

To summarize the attitude toward the mongoose which the investigators have developed in the course of this study, we can say only that the case is not clear-cut. We do not agree with those who call the mongoose an unmitigated evil in Hawaii, nor could we advocate this creature as a desideratum. It is an animal of a small carnivorous type which was unrepresented in the Hawaiian bio-community before its introduction. It adds a component found universally in more mature continental communities, thus it has helped to mature the Hawaiian bio-community.

From the short-term point of view it is asked how the mongoose affects us today. We can say that several species of animals, including destructive rodents

or insects as well as desirable birds or other types, have been reduced or even locally extirpated in a limited number of cases. However, the number of species, if any, wholly extirpated because of the mongoose alone must be exceedingly small; without doubt, man through direct predation and by his land-use practices has had a far greater influence on the reduction of native species in Hawaii than has the mongoose. From the long-term point of view it is asked whether the mongoose will have predominantly undesirable effects on the Hawaiian biota as a whole. The question then arises as to whether or not permanent harm is done to a species because its numbers are reduced by predation. Many adjustments may be made to predation by prey species in the course of time, and, short of extirpation or excessive reduction bordering on extinction, mongoose predation may not represent harm in the long term view. Because in many cases the prey species are exotics, it is extremely difficult to evaluate the effects of the mongoose (also an exotic) until a balance has become established between the prey species and its new environment, irrespective of the effects of predation.

Most of the effects which we have discussed are exerted in the wild rather than in the home garden or cultivated tract, and a large part of the answer as to the usefulness of the mongoose must be derived from the position it adopts in the wild community. Here long term trends will be more important, if less apparent to man, than some of the disturbances produced in the home plot and plantation fields. The position one takes on the judgment of the mongoose in Hawaii will vary according to his scale of values, whether economic or naturalistic. Any particular economic interest, such as chicken raising or sugar cane production, will have a definite answer, but outside of these restricted spheres, the problem involves many reciprocal effects on a great variety of living creatures

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STUDIES ON THE BIOCHEMISTRY OF THE ARCTIC GROUND SQUIRREL

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Studies on the gas exchanges between hibernating mammals and the environment and between active mammals exposed to the cold and the environment suggest that an increased utilization of fat obtains (Prosser, 1950). Whether the conclusions, indicated by measurements of respiratory quotients (Benedict and

Lee, 1938) are supported by biochemical analyses is not known. As Gorer (1930) emphasized some time ago, further elaborate discussions of R.Q. values are fruitless. What is crucially needed is direct chemical information on metabolic phenomena, in order to justify the R.Q. concept and to decide definitely what type of metabolism is going on. It was, therefore, decided to investigate various chemical constituents in the Arctic ground squirrel, *Citellus parryi barrowensis*, under different environmental conditions in order to ascertain the chemical effects of hibernation and of fasting on this species.

All specimens were collected in the vicinity of Teshekpuk Lake and Anuktuvuk Pass, Alaska. The squirrels used in the starvation experiments were fasted for approximately six weeks in the summer of 1949. Water was given *ad libitum*. For hibernation studies, squirrels were put into outdoor cages at Point Barrow during the late summer of 1949. They dug burrows, as in their native habitats. In March of 1950, the hibernating squirrels were dug out and the tissues removed for analysis. Some studies were made in the field at the Arctic Research Laboratory, others were done at St. Louis University.

For chemical analyses, blood was removed from the left ventricles of living squirrels. The urine was collected for an 18-hour period in pyrex vessels and analyzed immediately.

Mr. James Gleeson and Mr. E. V. Orsi, graduate students in our department, rendered invaluable technical assistance on this project.

Nitrogen studies.—Blood and urinary nitrogen values were estimated colorimetrically using the methods outlined for the Lumetron Colorimeter (Anon.). Table 1 shows the mean values for various urinary constituents from the Arctic ground squirrel. Values for animals kept in captivity for one year are essentially the same as for those held captive for only two weeks.

Table 2 shows the mean values for some nitrogenous constituents of squirrel serum, compared with values from the literature for human plasma. The results show that serum nitrogen values are practically identical in both groups of squirrels, but that, with the exception of uric acid, they vary from human values. NPN and urea N in the squirrel are about twice those values in man. The urinary volume in cc. excreted per day is also apparently unaffected by prolonged captivity.

From calculations it is evident that in the ground squirrel serum about 61 per cent of the NPN is urea N; in human plasma only about 50 per cent is urea N. The ratio of uric acid N/urea N $\times$ 100 in the squirrel serum is 4.0; in human plasma, 12.0. Apparently, appreciably greater amounts of uric acid N are present at a given time, relative to urea N, in human plasma than in ground squirrel serum.

It is known that, during hibernation, there is a remarkable fall of protein metabolism in the woodchuck, as reflected in the urinary nitrogen values. Qualitatively, however, protein metabolism is not altered (Carpenter, 1938).

Blood Sugar.—Blood sugar of fasted and captive specimens was estimated according to the Somogyi-Schaffer-Hartmann method (Hawk, Oser, and Summerson, 1947). The blood sugar of hibernating squirrels was measured according

to the method of Nelson (1944), which gives results significantly the same as the other method.

Table 3 lists the values for blood reducing-sugar from captive squirrels fed in the laboratory, from fasting squirrels, and from hibernating squirrels, respectively.

The evidence indicates that there is no difference in blood reducing-sugar in hibernating as compared with captive squirrels. On the other hand, squirrels which were fasted for about six weeks show a marked decrease in blood sugar, from a value around 150 mg. per 100 cc. to 44 mg. per 100 cc. (Table 3).

TABLE 1.—*Some nitrogenous constituents in the urine of Citellus parryi barrowensis*

SUBSTANCE	GROUP I ONE YEAR CAPTIVITY	GROUP II TWO WEEK CAPTIVITY
Urinary volume, cc./hour	2.8 ± 1.2	3.3 ± 1.7
Urea nitrogen, mg./100 cc./hr.	52.9	52.4
Urea mg./100 cc./hr.	110.3 ± 61.7	112.4 ± 46.9
Uric Acid, mg./100 cc./hr.	1.4 ± 0.5	1.6 ± 0.8
Creatinine, mg./100 cc./hr.	1.9 ± 0.8	1.7 ± 0.9
Urinary volume, cc./day	67.2	79.2

TABLE 2.—*The average values for various nitrogenous constituents in the serum of Citellus and the plasma of man. Values in mg. per 100 cc.*

SUBSTANCE	GROUP I ONE YEAR CAPTIVITY	GROUP II TWO WEEKS CAPTIVITY	HUMAN PLASMA
Total N	1067	895	1100
NPN	65.1	63.4	26
Urea N	41.0	37.4	13
Uric acid	4.0	3.1	3.9

In the chipmunk there is an apparent seasonal variation in blood sugar, with high values during midsummer. Moreover, prolonged chilling of this species results in marked decrease of blood sugar (Woodward, and Condrin, 1945).

Apparently, there is some mechanism, in operation during hibernation, which serves to maintain the blood sugar level of the Arctic ground squirrel fairly constant. On the other hand, this mechanism is not operative during fasting, as is indicated by the marked decrease in blood sugar. Consequently, insofar as blood sugar is concerned, prolonged fasting and hibernation are dissimilar processes.

It is known that, in cattle, fasting results in a rapid decrease in blood sugar, whereas, in the dog, pig, cat, and man a normal level is maintained (Dukes, 1947). Like cattle, the ground squirrel is normally herbivorous and shows a decreased blood sugar during fasting.

Lyman (1943) studied short term (48 hours maximum) hibernation induced by cold in *Citellus tridecemlineatus*. He found wide individual variations in blood sugar values; and in general his results are lower than those in the present paper:

range of blood sugar, 64.8 to 119 mg. per 100 cc., average value, 85.3 mg. per 100 cc. He concludes that "although a small diminution in blood sugar accompanies hibernation, it is not essential to the maintenance of the torpid condition."

Table 6 shows the range of blood sugar values for a variety of mammals. It is evident that in *Citellus parryi barrowensis* the blood sugar falls within the upper part of the mammalian range.

Lipids.—Lipid analyses were done using the same procedures as previously (Wilber and Musacchia, 1950).

Analyses of blood from *Citellus* have to date indicated no variations in blood lipids during different seasons of the year (Wilber and Musacchia, 1950). Table

TABLE 3.—*The values for reducing-sugar in the blood of ground squirrels under various conditions. Values in mg. per 100 cc.*

SPECIMEN	FASTING	HIBERNATING	CAPTIVE
1	49	180	175
2	58	190	102
3	31	140	136
4	56	100	159
5	34	125	194
6	39	190	—
7	44	125	—
8	—	135	—
9	—	140	—
10	—	150	—
Mean	44.4	147.5	153.2

7 shows the average blood lipids in *Citellus* compared with those in other animals. It is evident that the blood lipids in the Arctic ground squirrel are high compared with other mammals. The high cholesterol value of 224 mg. per 100 cc. is striking in comparison with the usually low values found in herbivores generally.

Table 4 shows the lipid values for the livers and kidneys from hibernating ground squirrels. Table 5 shows similar values for fasting squirrels. The only apparent differences are the significantly higher cholesterol values in Table 5.

This fact is reflected in the different lipid ratios of phospholipid, and of fatty acid to cholesterol. For the fasting squirrels the ratios of phospholipid/cholesterol (calculated from mean values) are: liver, 8.8; kidney, 9.5; for hibernating squirrels: liver, 15.0; kidney, 11.5. The fatty acid/cholesterol ratios for fasting animals are: liver, 11.6; kidney, 10.8; for hibernating animals: liver, 17.0; kidney, 9.0.

At first the routinely high concentration of total lipids in the livers of the squirrels may appear strange relative to the values usually encountered in laboratory animals. Many domestic and laboratory species have less liver lipids than those reported in this paper. On the other hand, there is evidence that wild animals of the same species have higher liver lipids than those kept in captivity on a balanced diet (Kellogg, 1939). The high values in the present work may be,

in part, a reflection of the lipid condition of the tissues from squirrels in the wild state (Wilber and Musacchia, 1951). No tissue vitamin measurements were made. The results do suggest, however, that further lipid studies should be made of these Arctic animals in captivity, feeding on a laboratory ration.

The total liver fatty acids in the present results are significantly lower than those in squirrels obtained during summer months (12 per cent) but higher

TABLE 4.—*The amounts of lipids in tissues from hibernating ground squirrels. Values in per cent fresh tissue*

SPECIMEN	TOTAL LIPID		CHOLESTEROL		PHOSPHOLIPID	
	Liver	Kidney	Liver	Kidney	Liver	Kidney
1	6.0	3.6	.32	.33	4.0	3.6
2	5.0	4.0	.30	.41	6.0	4.7
3	5.6	—	.33	—	4.0	—
4	6.3	4.3	.38	.42	5.6	2.6
6	6.5	2.7	.36	.36	5.7	—
7	6.0	4.6	.52	.43	4.2	7.9
8	4.0	1.4	.32	.38	5.4	3.5
9	8.4	3.0	—	—	8.1	4.5
10	7.4	4.7	—	—	6.0	4.6
Mean	6.1	3.5	.36	.39	5.4	4.5

TABLE 5.—*The amounts of lipids in tissues from fasting squirrels. Values in per cent fresh tissue*

SPECIMEN	TOTAL LIPID		CHOLESTEROL		PHOSPHOLIPID	
	Liver	Kidney	Liver	Kidney	Liver	Kidney
1	3.5	—	—	—	4.6	—
3	6.5	4.8	.61	.43	3.2	4.0
4	6.6	—	.40	—	5.0	—
5	5.7	5.5	.51	.48	5.0	3.8
6	6.0	5.7	.55	.48	4.0	4.7
7	6.4	4.0	.43	.47	4.7	5.0
Mean	5.8	5.0	.50	.46	4.4	4.4

than in squirrels just before hibernation (4 per cent; Wilber and Musacchia, 1950). Similarly the liver phospholipids are lower in the present squirrels than in those taken in the summer, but higher than those taken just before hibernation.

The results suggest that hibernation is physiologically merely slow starvation insofar as the lipids of the squirrel body are concerned.

The reason for the elevated tissue cholesterol (Table 5) in the fasting squirrels is not clear; it is higher in these animals than in either summer squirrels, or in

those immediately prior to hibernation (Wilber and Musacchia, 1950), or in hibernating squirrels (Table 4).

If liver phospholipid level is an indicator of rate of fat turnover (and according to Bloor, 1943, such is probable), the present work and previous results fall into a pattern. In the summer, the ground squirrel is turning over fat at a rapid rate preparatory to hibernation. (liver phospholipid, 6.3 per cent) (see also, Wade, 1948). Just before hibernation, the rate of turnover decreases (liver phospholipid, 3.8 per cent). During hibernation, there is another increase of fat usage (liver phospholipid, 5.4 per cent). This fact is in accord with results of R.Q. measure-

TABLE 6.—*The range of blood sugar values in various mammals. Values in mg. per 100 cc.*

ANIMAL	MINIMUM	MAXIMUM
Citellus	102	194
Pig	40	250
Cow	40	60
Sheep	40	65
Goat	130	260
Horse	60	110
Dog	70	100
Man	70	90

TABLE 7.—*A comparison of the lipids in the blood of various animals. Values in mg. per 100 cc.*

ANIMAL	FATTY ACIDS	CHOLESTEROL	PHOSPHOLIPID
Citellus	833	224	625
Man	200–450	150–260	150–250
Rabbit	280	100	210
Guinea pig	102	23	15
Caribou	377	68	125
Eel	1957	163	883

ments which show that during hibernation the R.Q. value is low, indicating the oxidation of fat (Prosser, 1950).

The indicated increase of fat turnover during hibernation probably serves to supply the small energy requirements at that time (Kayser, 1950). Moreover, it may be correlated with the constant blood sugar level; the squirrel may be using fat to replenish muscle and liver glycogen stores which are being diminished in maintaining the blood sugar constant.

In the fasting animal, fat is also being used, and at a rate apparently comparable to that in the hibernating squirrel. Blood sugar, however, is not maintained at a constant level, but rather shows a marked decrease during fasting. It is difficult to relate carbohydrate and fat usage in the fasting squirrel on the basis of available information.

It is known, nevertheless, that in "all animals that have been made to fast

for any considerable period of time the R.Q. approaches 0.7, which indicates that the principal substance being oxidized is fat" (Dukes, 1947). The purely chemical evidence in the present report is in accord with this conclusion.

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NOTES ON THE MAMMALS OF WESTERN TENNESSEE

BY WOODROW W. GOODPASTER AND DONALD F. HOFFMEISTER

Collecting and field observations in the western part of Tennessee of nearly four months duration have provided new and additional information on the mammals of that part of the state. The field work was done principally in the vicinity of Reelfoot Lake, Obion and Lake counties, Tennessee, at various times in the years 1937, 1940, 1949, 1950, and 1951, and in 1950 in Lauderdale County. Species of mammals previously not taken or not recorded, so far as known, from western or northwestern Tennessee include *Neotoma floridana illinoensis*, *Cory-*

norhinus macrotis, *Peromyscus nuttalli aureolus*, *Peromyscus maniculatus bairdi*, and *Sigmodon hispidus hispidus*. These notes are intended to augment and supplement the accounts of Rhoads (1896), Kellogg (1939), and Calhoun (1941), and to provide a more nearly complete picture of the animal life of western Tennessee, particularly in the vicinity of Reelfoot Lake.

Before the earthquake of 1811–1812, the area that is now Reelfoot Lake and the surrounding territory was heavily timbered, swampy bottomland of the Mississippi River. Here grew such trees as gum, pecan, maple, sycamore, and cypress. Cane thickets were prevalent and there was little opportunity for agricultural activity.

Following the formation of Reelfoot Lake after the 1811–12 earthquake, many changes took place. Much of the mature timber was slowly but surely cut away. After this came the clearing of the land for cotton, soybeans, and pasture. At the present, farming has extended to the lake's edge and only the lake itself, which is approximately four by eleven miles, has not felt the tools of cultivation. There are, however, many sloughs and drainage ditches that extend for several miles in places back into the farm land. These spots of nearly original conditions provide food and habitat for many small mammals. On the northwest side of Reelfoot Lake, the state of Tennessee has set aside a portion of the more heavily timbered area as a preserve for deer and other game animals. All of these changes have no doubt played an important part in the mammalian fauna of Reelfoot. For example, with the cutting and clearing of the forest, the range of *Peromyscus gossypinus* has been greatly reduced, but at the same time habitats for *Oryzomys palustris* and *Sigmodon hispidus* have been extended. These changes probably have not greatly reduced the abundance of small mammals in this area, for a line of 75 traps in March, 1951, produced 125 specimens over a period of three nights.

Some collecting localities from which these data were assembled are as follows: *Lake County*: 1½ mi. E Tiptonville; 2 mi. E Tiptonville (= Blue Bank); 3 mi. E Tiptonville; 3½ mi. E. Tiptonville (= Caney Island); 2 mi. SE Tiptonville (= Sunkist Beach). *Obion County*: 3½ mi. SE Samburg; 4 mi. E Tiptonville; 4½ mi. E Tiptonville (= Lasiter's Corner); 6 mi. E Tiptonville; 4½ mi. NE Tiptonville (= Cranetown or Big Ronaldson Slough); 6½ mi. NE Tiptonville (= State woods near Gray's Landing); 8½ mi. NE Tiptonville; 9 mi. NE Tiptonville (= Walnut Log); 10 mi. NE Tiptonville (= Mt. Manuel Cemetery); and ½ mi. SW Samburg. *Lauderdale County*: Ripley; various localities 1.9 to 3.8 mi. E Open Lake.

Most of the specimens from the vicinity of Reelfoot Lake were collected by Goodpaster. Those from Lauderdale County were obtained by Lowell S. Miller and I. L. Firschein. Specimens marked with an asterisk(*) are in the collection of Woodrow W. Goodpaster; those marked with a dagger (†) are in the University of Illinois Museum of Natural History.

ACCOUNTS OF SPECIES

Didelphis virginiana virginiana Kerr. Opossum.—The opossum was found to be common all around Reelfoot Lake. A specimen was seen dead on the road at Lasiter's Corner, another near Samburg, one at Blue Bank, and one was observed along the edge of the road at Sun-

kist Beach. An adult was chased along the road 1¼ mi. SW Samburg, and fell into a ditch, but swam rapidly 14 feet to the other side.

Scalopus aquaticus machrinus (Rafinesque). Eastern mole.—Twenty-three specimens were collected from the following localities: 2 mi. SE Tiptonville (3*), Sunkist Beach (4*, 4†), 3 mi. E Tiptonville (2*), 2 mi. E Tiptonville (5*, 1†), 4 mi. NE Tiptonville (3*), 4 mi. E Tiptonville (1*). Of these specimens, eleven are exceedingly pale in dorsal coloration, and probably are paler than any non-albinistic individuals of the species. Fifteen of the specimens have a heavy coppery-colored wash on the underparts.

Of the eleven pale specimens, five are darker than the other six, but all can be readily distinguished from all specimens examined of the races *machrinus*, *machrinoides*, *howelli*, and *pulcher*. Of the remaining twelve specimens, about half are as dark as the darkest *machrinus*, and all twelve could readily be referred to that race on the basis of dorsal coloration.

The fifteen specimens with coppery-colored underparts show resemblance to *S. a. pulcher*, but differ from that race in brighter and more extensive coppery color. They further differ from *pulcher* in larger size throughout (Table 1).

TABLE 1.—*Measurements, in millimeters, of Scalopus aquaticus*

SUBSPECIES	LOCALITY	NO. AND SEX	TOTAL LENGTH	TAIL	HIND FOOT	GREATEST LENGTH SKULL	PALATILAR LENGTH	MASTOIDAL BREADTH	INTERORBITAL BREADTH	MAXILLARY TOOTHROW
machrinus	Reelfoot Lake, Tennessee	13♂	180.5	34.5	22.5	37.2	16.6	19.7	8.1	11.8
		8♀	173.5	33.5	21.5	36.1	15.6	19.0	8.1	11.5
"	vic. Cincinnati, Ohio	9♂	181.6	33.0	22.4	37.8	16.2	19.8	8.0	12.0
		6♀	173.6	32.8	20.6	36.8	15.6	19.3	7.9	11.6
"	Fayette & Christian cos., Illinois	3♂	175.3	29.0	23.7	37.8	—	19.8	—	12.1
"	Fulton Co., Illinois	1♂	185	33	21	38.8	—	20.1	—	12.2
		2♀	188	33	22.5	38.4	—	19.8	—	12.1
machrinoides	Boone Co., Missouri	5♂	171.6	27.4	23.2	38.1	—	20.0	—	12.1
		6♀	172.1	31.2	21.7	37.5	—	19.7	—	11.9

On the basis of dorsal coloration, slightly less than 50 per cent of the moles in our sample from Reelfoot Lake are distinct from any of the geographically adjacent subspecies. On the basis of coloration of underparts, about 65 per cent are distinguishable from specimens of adjacent races. Other than for color, specimens from Reelfoot Lake seem indistinguishable from *S. a. machrinus*, and the color of some specimens is the same, as far as the eye can tell, as in *machrinus*. For the present, the specimens from Reelfoot Lake are referred to *S. a. machrinus*.

There is a possibility that moles have only relatively recently invaded the region of Reelfoot Lake as the timber has been cleared away and the land opened up to agriculture. In this new area, certain mutations or gene combinations may have become established, perhaps in a relatively short time. If the pale dorsal coloration and coppery-colored underparts represent such changes, these mutations have not become well established, although the population of moles in the vicinity of Reelfoot Lake may represent an incipient subspecies.

Sorex longirostris longirostris Bachman. Long-nosed shrew.—One specimen*, a male, was captured beneath a board on a sandy slope just above Sunkist Beach, May 5, 1950. This specimen was taken by hand and kept in captivity for several days for photographing. When placed in a wooden nail keg, about three feet deep, the shrew would readily climb out when the top was removed. Its actions were exceedingly fast and it would not hesitate to

bite. It fed readily on the carcasses of *Microtus* and *Peromyscus* while in captivity. Traps baited with bacon and set in the runways of *Pitymys* and *Blarina*, and in other seemingly suitable locations near where the specimen was taken, failed to yield additional specimens. A long-nosed shrew was obtained near the northern end of Reelfoot Lake by Perrygo and Schaefer for the U.S. National Museum in 1937 (see Kellogg, 1939: 245).

The specimen from Sunkist Beach has the following measurements (in millimeters): total length, 81; tail, 31; hind foot, 11; ear, 8; condylobasal length, 14.2; palatal length, 5.7; cranial breadth, 7.5; interorbital breadth, 3.1; maxillary breadth, 4.5; maxillary toothrow, 5.2.

Blarina brevicauda carolinensis (Bachman). Short-tailed shrew.—Short-tailed shrews were common in all areas trapped around Reelfoot Lake. Traps baited with meat and set in either wooded places or in fields procured specimens. In drier parts of the swampy woodlands around the lake shore, *Blarina* were often found under fallen logs or heavy pieces of bark. After heavy spring rains, it was not unusual to take by hand four or five shrews from under or inside rotten logs in a short search in the woods. The shrews apparently came to these logs for the abundance of food and drier nesting sites.

Specimens were obtained as follows: Tiptonville, 6 mi. E (4*), 2 mi. E (6*), 2 mi. SE (5*, 1†), 3 mi. E (1†), 7 mi. NE (2†); state woods (5*). In Lauderdale County, four specimens were taken 3.8 mi. E Open Lake and two in a cemetary at Ripley.

Pipistrellus subflavus subflavus (F. Cuvier). Eastern pipistrelle.—Only two specimens were taken, one from Blue Bank* (May 29, 1950) and the other from Walnut Log* (June 15, 1950). This species was very common at Walnut Log where numbers were seen flying around the biological station. They were also common at Sunkist Beach and Blue Bank.

Lasiurus borealis borealis (Müller). Red bat.— Three specimens* were shot in the early evening along the lake shore at Blue Bank. Several others were observed flying around the cypress and pecan trees close to the lake. There is little doubt but that the red bat was one of the commonest bats in the Blue Bank and Sunkist Beach areas in late May and early September of 1950. This bat was common at the south end of Lake Isom, Lake County, where one was shot on June 10, 1951, 3½ mi. NE Ridgely†.

Corynorhinus macrotis (LeConte). Eastern big-eared bat.—On May 25, 1950, a single specimen was taken from an open cistern, just across the road from the Mt. Manuel Cemetary. The cistern was about twenty feet deep and built in the shape of a bottle, with the open top about 2½ feet in diameter and extending about three feet above the ground. There was just an inch or so of water at the bottom. The bat was hanging about three feet from the top, but when disturbed immediately flew to the bottom and started circling. By cutting a long grapevine that reached almost to the bottom, and swinging it in a circular motion behind the flying bat, it was forced to attempt an escape through the opening at the top, where it was taken by hand.

The same cistern was visited again on September 2, 1950, and at this time several individuals were hanging in a clump at the top. Fifteen of these were collected. On a return visit on March 13, 1951, bats were again noted, hibernating near the bottom of the cistern. At this time they were not hanging in a single clump, but in two or three small clumps, and a few were hanging individually. Twenty-five specimens were taken at this time. The bats were cold and sluggish and made no attempt to escape when placed in a cage. However, two or three days later, when the temperature was much warmer, these captive specimens showed considerable activity and mating began.

Average measurements, with extremes, in millimeters, of the specimens collected above are as follows: Twenty-one males: total length, 97.0, (93–102); tail, 50.1, (45–53); hind foot, 11.3, (10–13); ear, 34.6, (33–36); tragus, 13.7, (10–18). Twenty females: total length, 98.8, (92–105); tail, 50.0, (44–54); hind foot, 11.7, (11–13); ear, 35.2, (33–37); tragus, 13.8, (11–17).

Corynorhinus macrotis has not previously been recorded from western Tennessee, and this locality probably represents a part of the northern limit of this species. All of the big-eared bats were anxiously examined to determine if *C. macrotis* and *C. rafinesquei* might be occurring together here. Only one species was detected. As a matter of fact, the two species

apparently do not occur together at any place. Hamilton (1943) and Allen (1916: 341) mistakenly referred material from central Kentucky to *C. rafinesquei*. This species does not quite extend southward as far as the southern boundary of Illinois or Indiana. The two northernmost records for *C. macrotis* apparently are Mitchell, Indiana (see Allen, 1916: 351), and Bowling Green, Kentucky (see Miller, 1897: 52).

Procyon lotor varius Nelson and Goldman. Raccoon.—Judging from "signs," raccoon are common around Reelfoot Lake. Tracks were equally numerous around Lake Isom. The 'coon is the commonest large mammal in this part of western Tennessee. Two young were found in early May near Cranetown. There is little doubt that raccoons often visit Cranetown to rob the nests of Ward's heron, American egret, and double-crested cormorant, or to eat the fish that are brought to the young birds, but are accidentally dropped over the edge of the nest. The abundance of food in the form of frogs, crayfish, and fish, and the large number of suitable den sites in cypress and other large trees, around Reelfoot and the marshy areas in western Tennessee, provide ideal habitats for raccoons.

Mustela frenata noveboracensis (Emmons). Long-tailed weasel.—Long-tailed weasels are not common in the western part of the state. Lewis Burrus saw three weasels in white pelage traveling together near Reelfoot about the winter of 1938. These are the only ones he could remember seeing there.

Mustela vison mink (Peale and Beauvois). Mink.—Very few mink tracks were noted. However, Lewis Burrus, state game protector, said that mink are common and a considerable number are taken each winter by local trappers. A trap line three-fourths mile long, in a grassy slough ¼ mi. E Blue Bank, yielded twelve mink during the winter of 1950–1951.

Lutra canadensis interior Swenk. River otter.—Lewis Burrus told us he had seen, in 1950, sign of otter on the east end of Horse Island (5½ mi. NE Tiptonville) and on Little Ronaldson Slough (4 mi. E Tiptonville). Waldon Fickle, assistant refuge manager, U. S. Fish and Wildlife Service, knew of otter on Horse Island in 1947 or 1948. An otter was trapped in the Lake Isom area, 3 mi. S Blue Bank, but we could not learn the date of this catch. Both Burrus and Fickle reported otter as common at one time around parts of Reelfoot Lake.

Mephitis mephitis subsp. Striped skunk.—Stripped skunks may be present in the Reelfoot Lake area, but they are rare. Lewis Burrus has never seen a skunk in the nearly 50 years he has been around the Lake. Waldon Fickle, who has been at Reelfoot Lake since 1911, knew of only two skunks that had been taken there in that time. Skunks from extreme western Tennessee may be referable to *M. m. nigra*.

Vulpes fulva fulva (Desmarest). Red fox.—We were told that red fox are "common" in the bottomland around the lake. They certainly were not abundant, for little "sign" was encountered. Kellogg (1939: 264) has indicated that the red fox is a non-native mammal in Tennessee, with an introduction or migration into western Tennessee about 1845.

Urocyon cinereoargenteus cinereoargenteus (Schreber). Gray fox.—Gray foxes reportedly occur principally in the hills or bluffs and are considered more rare than red foxes.

Marmota monax monax (Linnaeus). Woodchuck.—No woodchucks were collected although they are fairly common. Animals and burrows were noted along the bluffs around Lasiter's Corner. Burrows examined on Caney Island proved to be in use. A very large specimen of woodchuck inhabited a burrow beneath a cabin (3½ mi. SE Samburg) while in the attic was a family of woodrats.

Tamias striatus ohionensis Bole and Moulthrop. Eastern chipmunk.—Five* chipmunks were taken from a brushy area along the bluffs, 1 mi. SE Lasiter's Corner, and were fairly common all along the bluffs at least as far as Samburg. No specimens were ever encountered close to the lake as habitats there were not suitable. Lewis Burrus reports that chipmunks are fairly common along Reelfoot Creek just east of Walnut Log.

Specimens of *Tamias striatus* from northwestern Tennessee certainly are not referable to *T. s. pipilans* Lowery, of Louisiana and western Mississippi, for they are not as large nor do they possess the rich reddish color of the head, neck, and rump of *pipilans*. Dr. George Lowery has checked these specimens with his material of *pipilans*. Specimens from north-

western Tennessee differ from specimens of *T. s. striatus* (Linnaeus) from the Smoky Mountains in lighter coloration of back, especially in shoulder region, cheeks more ochraceous and less reddish, and ventral light eye line usually more distinct and broader. The Tennessee material resembles topotypes of *ohionensis* rather closely. However, they resemble just as closely a large series from Shenodoah National Park (*T. s. fisheri*). It is not clear to us whether *T. s. ohionensis* is to be regarded as a subspecies distinct from *fisheri*.

Sciurus carolinensis carolinensis Gmelin. Gray squirrel.—Gray squirrels were common all along the bluffs although very few were noted near the lake. Signs of their cuttings on beech and oak were observed on several occasions.

Sciurus niger rufiventer Geoffroy. Fox squirrel.—In 1940, fox squirrels were common on the northwest side of Reelfoot Lake near Phillipy. Here, on June 16, ten* specimens were collected and many others seen. Melanistic specimens were noted twice at this time. In 1949 and 1950 this same area was visited, but much of the land had been prepared for cotton and soybeans by clearing of the timber, and no squirrels could be found. In the state park at Blue Bank several individuals, including some females with young, were seen in 1949, 1950, and 1951.

Castor canadensis subsp. Beaver.—Waldon Fickle said that beaver were gone, or nearly gone, from Reelfoot Lake when he first came there in 1911. Four specimens, thought by local residents to be from Missouri, were introduced on the Lake in 1942 or 1943, and some beaver are reportedly around the lake now (1951).

Reithrodontomys humulis humulis (Audubon and Bachman). Eastern harvest mouse.—Two specimens were collected in Lauderdale County (one from 3½ mi. E Open Lake†, one from 2 mi. E Open Lake†) by L. S. Miller and I. L. Firschein. One was taken on a hillside covered with a heavy growth of bluestem and the other in a small apple orchard grown up with blue grass (see Miller and Robertson, 1950: 1). Harvest mice have never been taken, to our knowledge, in the vicinity of Reelfoot Lake.

Peromyscus maniculatus bairdi (Hoy and Kennicott). Deer mouse.—Deer mice are uncommon in western Tennessee. One was obtained 3½ mi. NE Tiptonville*, and due east of Proctor City, on June 7, 1940, in second growth timberland that was being cleared for a field. Another was taken near Sunkist Beach, 2 mi. SE Tiptonville* on March 12, 1951, along a fencerow in a soybean field. In the trapping of hundreds of *Peromyscus* around Reelfoot, no other *Peromyscus maniculatus* were taken. In Lauderdale County, one specimen of *P. maniculatus* was taken at 1.9 mi. E, another at 2 mi. E, and another at 3.8 mi. E Open Lake.

Peromyscus leucopus leucopus (Rafinesque). White-footed mouse.—*Peromyscus leucopus* was abundant in all wooded areas trapped. These mice were also abundant in many abandoned tenant houses and other out buildings. Since white-footed mice were often found in association with the chicken snake (*Elaphe obsoleta confinis*) and the black king snake (*Lampropeltis getulus nigra*), the mice may serve, in part, as food for these snakes. On May 10, 1937, at the northern end of Reelfoot Lake, but just inside Kentucky, a female and five young *Peromyscus leucopus* were taken from a standing hollow stub, about six feet high. The young were only a few days old. This family of five consisted of two normally-colored individuals, one "partial" albino, and two that were pure white, but with normal pigmentation of their eyes. This family was kept in captivity until they died or escaped. The two white specimens were both males, and in captivity one lived for two years, two months, ten days, the other for three years, four months, twenty-six days.

Specimens were taken at the following localities: Sunkist Beach (16*, 7†); state woods (2*); Blue Bank (1*); Tiptonville, 2 mi. E (3*), 6 mi. E (9*, 2†), 4 mi. E (8*, 5†), 4 mi. NE (2*), 5 mi. NE (1*).

Peromyscus nuttalli aureolus (Audubon and Bachman). Golden mouse.—Two specimens* of the golden mouse were trapped along the edge of the state woods, 6½ mi. NE Tiptonville, on March 12, 1951. Traps were set at the base of a 7½-foot fence post. On the top of this post, in a thick clump of poison ivy vines, these mice had a nest. Along the lake shore in the state woods, two other nests were found, but they did not contain mice. The nests were fresh, and there is little reason to doubt that the mice were in the immediate vicinity. Three

other specimens† were collected at this same locality, in the hackberry-gum-sycamore community, in April of 1943 and 1946. Almost two days were spent trying to locate other areas around Reelfoot Lake that might be inhabited by *P. nuttalli*, but none could be found although many looked suitable. In Lauderdale County, one specimen† was taken 1.9 mi. E Open Lake.

The currently recognized subspecies of *P. nuttalli* (*nuttalli, aureolus, lewisi, flammeus*) are difficult to distinguish on the basis of our present knowledge. Specimens from western Tennessee appear nearly indistinguishable, when account is taken of age and seasonal variation, from three specimens from southern Illinois, one from eastern Missouri, and four from eastern Kentucky. It seems best at the moment to refer our Tennessee material to *P. n. aureolus*.

Peromyscus gossypinus megacephalus (Rhoads). Cotton mouse.—Cotton mice were generally found in the same type of habitat, principally swamp woodlands, as that occupied by *Peromyscus leucopus*. An occasional individual could be trapped in most any wet woodland, but in some areas they were more abundant than in others. Nests were found in and under fallen logs. Some nests were found beneath heavy moss on floating logs in the sloughs. When such nests were disturbed, the mice readily took to water.

Near Gray's Landing, in March, 1951, seventy traps in three nights caught 34 specimens, all of this species. Mice were caught in many traps set along fallen logs and brush piles, yet when logs were turned over, in search for their hiding places, no specimens were found. Abundant sign in the form of cuttings on hickory nuts, found in sheltered places such as hollow logs, or the seed pods or fruit beneath sycamore trees, gave evidence of their presence. Throughout the winter months, cotton mice may seek dry retreats well above ground in dead snags and hollow trees.

Specimens were saved as follows: Sunkist Beach (4*); state woods (21*, 8†); Tiptonville, 2 mi. E (1*), 4 mi. E (2*), 6 mi. E (3*), 4 mi. NE (1*), 2 mi. NE (1*).

Oryzomys palustris palustris (Harlan). Rice rat.—Rice rats are well distributed and fairly common in the bottomlands around Reelfoot Lake. Their nests are found in a variety of places. In cultivated fields along the edge of the lake some nests were found under clumps of soybean stubble that had been discarded by the combining process. Others were found under old boards and drift wood, under pieces of paper, in hollow stumps and logs, and in nests woven in the sawgrass a foot or so above the water. Nests and tracks of these rats were numerous along the lake shore. Many of the nests in the hollow logs and stumps were uninhabited as these nests had been under high water shortly before our inspection. Rats that nested in the sawgrass would jump or dive into the water when the nest was disturbed. By standing quietly, near the nest, the rat would sometimes return within a few minutes. In the sawgrass along the shore, platforms were often constructed. Food was carried here to be eaten.

Along the fencerows adjacent to sloughs, rice rats often constructed their nests in much the same fashion as *Peromyscus nuttalli*. Grass and vines were woven into a dome-shaped shelter. In one such nest a female and seven young were found. They were caught by quickly grabbing the entire nest. In the winter and early spring, when high water invades their usual habitats along the lake shore, rice rats move back, ahead of the water, into drier situations, although these new areas are generally of a swampy nature also. In March, 1951, *Oryzomys* and *Sigmodon* were trapped in the same runways, ½ mi. SW Samburg. At Lasiter's Corner and ½ mi. W Lasiter's Corner there were colonies of *Sigmodon* (no *Oryzomys*). Between these two colonies of *Sigmodon*, in places that were swampy with only an occasional small area of semi-dry ground, *Oryzomys* were predominant. Here, in March, immature specimens of *Oryzomys* were taken. There is indication that, at Reelfoot Lake, *Oryzomys* breeds throughout most of the year.

One of the chief items of food for rice rats in the vicinity of Reelfoot is the young of *Graptemys pseudogeographica kohni*, *G. geographica*, *Chrysemys picta dorsalis*, *Pseudemys scripta elegans*, and *P. h. heiroglyphica*. The collecting and selling of baby turtles is a sizable "industry" at Reelfoot, and rice rats sometimes compete with man's interests here. Rice

rats even invade the live cages of turtle collectors. Empty shells of baby turtles were often found along the lake shore, indicating the presence of *Oryzomys* and their nightly forays in search of food.

We have followed Kellogg (1939: 282) in referring our specimens from western Tennessee to *O. p. palustris*. Goldman (1918: 28) has pointed out that specimens from here might be referred either to this race or *O. p. texensis*. Specimens were saved as follows: state woods (9*, 2†); Tiptonville, 4 mi. NE (1*), 2 mi. NE (1*), 4 mi. E (1*), 5 mi. E (1*); Sunkist Beach (5*, 5†); Lasiter's Corner (4*, 1†); ½ mi. SW Samburg (2*).

Sigmodon hispidus hispidus Say and Ord. Cotton rat.—The first indication of cotton rats at Reelfoot Lake was the discovery of part of the skull and a small piece of dried skin of an animal in a nest under a brushpile, ½ mi. SE Samburg. In September, 1950, a colony was found near the highway at Lasiter's Corner, and 4* specimens were taken. In March, 1951, a revisit to the area indicated that cotton rats were more plentiful. Well-defined runways in the thick grass and weed patches along the road were trapped and an additional 14* specimens secured. Another colony was found near Samburg and still another 8½ mi. NE Samburg. This colony was in a dense patch of blackberry and honeysuckle.

A nest was found under a discarded paper box along the road. Others were found under heavy clumps of grass and some in the open. The nests were very similar to those of *Microtus*, but much larger, being about 14 inches in diameter and made of finely-cut and woven grasses. Some were easy to see, and the presence of a rat could be detected by pulling the nest apart and feeling the inner chamber. If it was warm it was quite evident that a rat had just left. *Sigmodon* must have been at the peak of abundance at Reelfoot Lake late in 1950 and early in 1951. In 1937, 1940, and 1949, no specimens were noted.

In Lauderdale County, one specimen was taken 2 mi. E Open Lake. In Obion County, 13 were taken 4½ mi. SE Tiptonville and one 8½ mi. NE Tiptonville.

Our specimens are more reddish and larger than *S. h. texianus*, as known to us, and are referred to *S. h. hispidus*.

Neotoma floridana illinoensis Howell. Eastern woodrat.—Three* immature *Neotoma floridana* were trapped on June 7, 1950, in the attic of an abandoned cabin 3½ mi. SE Samburg. A large, open nest of shredded burlap had been used by them. Near this nest was a large pile of debris, including such items as broken parts of the globe of an oil lamp, pieces of paper, bottle caps, horse manure, and several hundred nests of the mud dauber (*Sceliphron*). In another cabin, 3 mi. SE Samburg, another nest was found. It too was composed chiefly of mud dauber nests that had either been picked off the walls and ceiling or picked up from the floor after they had fallen. A few seed pods of the honey locust, taken from a tree about a hundred yards away in an abandoned pig pen, were present. On the top of a shed beneath this honey locust was a large pile of opened seed pods and on the inside of the shed was another pile of pods that had been opened for the bean-like seeds. Runways along the outside of the cabin indicated that numerous trips had been made into the surrounding area, probably in search of food.

The two nests were visited again in March, 1951, and to the above-mentioned items that formed the nest had been added a large number of sticks, rags, leaves, and plants. Plants had been gathered just outside the cabins and were chiefly mint (*Perilla frutescens*). There was perhaps a bushel of the mint plants in and around each nest; these gave the entire attic a very fragrant odor. At this time an adult specimen* was taken at the nest 3½ mi. NE Samburg.

Still other nests of woodrats were found, but all were along the bluff and above the bottomland. Three basket-shaped nests, two in tangles of vines and one in the top of a fallen tree, were noted 3½ mi. SE Samburg. Each nest was composed of about two bushels of sticks, mosses, and leaves, all gathered from the immediate vicinity of the nest. These nests were 2½ to 3 feet above the ground. No rats could be found when the nests were examined but fresh droppings indicated that they had recently been visited. Another nest was about 8 feet above the ground in the branches of an osage orange tree 5 mi. NE Samburg. The nest was similar to that of a squirrel, except all crotches in the tree near the nest were used to anchor

the structure. It was evident that the nest had been built during the summer for all the leaves were still on the branches. Along the bluff, 6 mi. S Samburg, an occupied nest, built around a hollow, fallen log was discovered on March 25, 1951. At two openings into the log there were two houses—one with about one gallon of sticks, the other with nearly a bushel. Parts of the hollow log were used for food storage, and acorns and beechnuts were found therein. The female* in this nest was captured alive and gave birth to three young on April 11. At least two families of woodrats in the vicinity of Reelfoot Lake had litters of three young each.

Microtus ochrogaster ochrogaster (Wagner). Prairie vole.—In a small field composed of blue grass, dew berry, and broom sedge, 2 mi. E Tiptonville, *Microtus ochrogaster* were common in May, 1949, when 17 specimens were collected. During the previous winter (1948–49), this area, along the lake shore, had not flooded. Droppings, runways, and cuttings were plentiful. In May, 1950, *Microtus ochrogaster* were very scarce as this area had been inundated by earlier high waters. There is little doubt but that prairie voles are fairly well distributed throughout much of the area around Reelfoot Lake above the high water level. Specimens were saved as follows: Tiptonville, 1½ mi. E (2*), 2 mi. E (12*), 2 mi. NE (3*); Sunkist Beach (1*).

Pitymys pinetorum auricularis (Bailey). Pine vole.—Pine voles were abundant around Sunkist Beach where their burrows and runways could be found in any wooded area or heavy weed patch in fine sand. In one decayed log near Sunkist Beach, four pine voles were found in one nest. There was a large population around Sunkist Beach in May, 1950, and March, 1951. Other pine voles were taken from under debris left by high water along the south end of the Lake. Specimens were saved as follows: Sunkist Beach (18*, 3†); Tiptonville, 2 mi. E (4*), 6 mi. E (4*), 2 mi. NE (1*). In Lauderdale County, two specimens were taken 3.8 mi. E Open Lake.

Ondatra zibethica zibethica (Linnaeus). Muskrat.—Muskrats were common and evidences of their presence were found around all parts of the lake studied. In the sawgrass areas of the lake, muskrat houses were evident. Some of the rats lived in bank dens and others in the partly decayed butts of the cypress trees. In the early evening, individuals were occasionally seen in the sloughs along the road in both Obion and Lake counties.

Rattus norvegicus (Berkenhout). Norway rat.—Along the sloughs at Blue Bank, Norway rats were abundant. They were generally found close to habitation and none was encountered around the lake in the wilder situations.

Zapus hudsonius rafinesquei Bole and Moulthrop. Jumping mouse.—An adult male† jumping mouse was obtained in a grassy clearing of about one-third acre between the road and the heavily wooded bluff ¼ mi. ESE Lasiter's Corner, Obion County, on June 11, 1951. This was the only mammal trapped in the area during two nights, although runways, seemingly old and of *Microtus*, were evident. The grass and weeds were nearly knee-high in most places. Several places, very similar to this, were trapped, but this is the only *Zapus* collected. Calhoun (1941: 222) obtained an immature jumping mouse near Walnut Log on July 30, 1940.

The indistinctness of the dark dorsal band, large size (210 mm.), long tail (121 mm.), and large skull indicate that this specimen is referable to the subspecies *Z. h. rafinesquei*, previously recorded from southeastern Ohio, southwestern Indiana, and southern Illinois.

Sylvilagus floridanus mearnsi (Allen). Cottontail.—Cottontails were fairly numerous around briar and weed patches. In a patch of blackberry and honey suckle 8¼ mi. NE Samburg, five cottontails were seen in an area about 15 feet wide by 150 feet long. Many cottontails are killed on the roads around Reelfoot Lake. We have the impression that cottontails are not as abundant now as they were in 1895 when Rhoads (1896: 182) visited this area.

Sylvilagus aquaticus aquaticus (Bachman). Swamp rabbit.—A nest of a swamp rabbit, containing four young, was found 2 mi. E Tiptonville. Unlike the nest of *Sylvilagus floridanus*, it was built on top of the ground in a heavy weed patch. Stalks of dead weeds were pulled around the inner fur-lining.

Swamp rabbits are not as common at Reelfoot as they were in former times. Local resi-

dents speak of killing numbers in years past where a rabbit is now seldom seen. The swamp rabbits are, however, fairly well distributed. At the north end of Reelfoot Lake the completely fenced waterfowl preserve, commonly known as the goose pen, contains swamp rabbits. They apparently have no way to escape from this enclosure. When rabbits were jumped from their forms in the patches of dew berry and blackberry in the center of the pen, they would often follow along the fence. At one spot, the fence made a right-angled turn at a large corner post. With one member to drive the rabbit, another, hidden behind the corner post, could easily take the rabbit by hand as it hopped around the corner. The rabbits never seemed to look in any direction except straight ahead. Two specimens were taken in this manner.

Odocoileus virginianus subsp. Whitetail deer.—The native stock has long been exterminated from Reelfoot Lake, but an introduction consisting of about three bucks and seven does was made in 1932 or 1933. The herd has multiplied, chiefly on the northwest side of the Lake, and Lewis Burrus estimated in 1951 that it might number 125.

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NOTES ON MICE OF THE SPECIES *PEROMYSCUS BOYLEI* AND *P. PECTORALIS*

BY EMMET T. HOOPER

In his report on the mammals of the Sierra San Carlos, Tamaulipas, México, Dice (Univ. Mich. Studies, Sci. Ser., 12: 253, 1937) listed a series of specimens under the name "*Peromyscus boylii levipes*." Actually two forms are represented in that series. Fourteen of the 35 specimens are referable to *P. boylei*. They are from La Vegonia mine, 2900 feet elevation, at the lower edge of the pine belt. The remaining 21 examples exhibit morphological traits of *P. pectoralis*, although they average much larger than examples of any known race of that species. The specimens are from collecting stations in the Sierra as follows: Tamaulipeca Ranch, 1500 feet elevation; Marmolejo, 1700 feet; San José, 2000 feet; and La Vegonia mine, 2900 feet. Nineteen of the 21 specimens are from Tamaulipeca,

Marmolejo, and San José. These three localities are situated on brush-covered foothills below the pine belt. Field notes indicate that the form represented by these specimens was common on rocky slopes covered with lechuguilla, maguey, and low brush. It was less abundant or absent in the oak and pine belts higher in the Sierra. *P. boylei*, on the other hand, was common at La Vegonia mine and apparently was absent at the stations on the foothills. It should be noted that both species occur at La Vegonia.

There are no great differences in coloration between the samples of the two species. The series of *P. pectoralis* averages slightly grayer dorsally (the grayness is particularly prominent on the forehead and cheeks) and the dorsal, dusky stripe on the tarsus is narrower and shorter, barely or not at all encroaching on the white foot. Although these differences are real, they are nonetheless subtle, and on casual inspection the two series appear to be identical in coloration. In both, the upper parts are a mixture of Pinkish Cinnamon or Cinnamon (capitalized color terms from Ridgway, Color Standards and Color Nomenclature, 1912) and black, the fur mass appearing reddish brown. The underparts are white or Pale Pinkish Buff, with or without a buffy pectoral area; the basal bands of the hairs are plumbeous. Most of the specimens have a blackish eye ring. The tail is distinctly bicolor, fuscous dorsally and whitish, unmottled, ventrally.

The two series stand in greater contrast in size, scalation of the tail, and cranial dimensions. In those features, a sample of 18 *pectoralis* compared with a sample of 12 *boylei* shows: larger body size, the mean and observed range 104 mm. (99–110) in *pectoralis* and 98 mm. (90–104) in *boylei;* longer tail, 113 mm. (104–123) in *pectoralis* and 102 (97–109) in *boylei;* finer caudal scales, number of scales per centimeter (as determined on the dorsal stripe at a level 2 cm. from the base of the tail) 22 (20–25), compared with 20 (17–22); longer cranium, length of cranium 28.2 mm. (27.5–29.4), compared with 26.9 mm. (26.2–28.6). The greater cranial length in *pectoralis* is attributable principally to the greater length of the brain case, particularly in the parietal region. Rostral length is similar in the two series, thus shorter relative to cranial length in *pectoralis*. Molar teeth are smaller; length of molar row 4.1 mm. (3.8–4.4) compared with 4.5 mm. (4.1–4.9). The mesopterygoid fossa is narrower with respect to its length. Auditory bullae are about the same size in the two forms, thus, smaller relative to cranial length in *pectoralis*.

The samples of *P. pectoralis* from the Sierra San Carlos and from other parts of northeastern México appear to represent a race that, in my opinion, warrants recognition. For it I suggest the name

Peromyscus pectoralis collinus, new subspecies

Holotype.—Adult male, skin and skull; Univ. Mich. Mus. Zool. No. 61310; México, Tamaulipas, Sierra San Carlos, 12 miles northwest of San Carlos, San José, 2000 feet elevation; collected 11 July 1930 by Lee R. Dice; original No. 511.

Distribution.—Foothills of the Sierra San Carlos, the Sierra de Tamaulipas, and Sierra Madre Oriental in northeastern México. Known geographic range, from the vicinity of Monterrey south to Jaumave in the Sierra Madre and to the vicinity of Acuña in the Sierra de Tamaulipas. Known vertical range, from 1300 feet at Villagran to 2900 feet at La Vegonia mine.

Characters and comparisons.—Similar to *Peromyscus p. pectoralis*, but larger (head and body length averages 104 mm. in 16 specimens from the Sierra San Carlos, compared with 88 mm. in 15 specimens of *pectoralis* from Tolimán, Querétaro). Upper parts slightly darker and more reddish; tarsi slightly darker; cranium similar in proportions to that of *pectoralis*, but much larger and with rostrum longer relative to cranial length. Patterns of molar teeth similar to those in *pectoralis* and in other races of the species. Much larger and darker than *eremicoides;* buffy bands of hairs Pinkish Cinnamon in *collinus* and Pinkish Buff or Cinnamon-Buff in *eremicoides;* tarsi slightly dusky, rather than white. Differences from *laceianus* follow (20 examples of *collinus* from the Sierra San Carlos compared with 15 topotypes of *laceianus*): slightly larger; tail longer; upper parts darker; tarsi darker (pale dusky or pale buffy or whitish in *laceianus*); brain case narrower and longer (length of posterior part of cranium averages 11.1 mm. in *collinus* and 10.4 mm. in *laceianus*); mesopterygoid fossa narrower, relative to its length; auditory bullae smaller; and molar row shorter, relative to cranial length.

Color.—Fresh adult pelage (July specimens from the Sierra San Carlos). Upper parts warm cinnamon-gray, the buffy bands Pinkish Cinnamon and the basal bands Dark Mouse Gray: head predominantly gray, the buffy hues inconspicuous; underparts creamy white, with or without a buffy pectoral spot; a blackish eye-ring; ears evenly Fuscous; forefeet and hind feet white; dusky area of hind legs extending onto upper surface of tarsal joint; under surface of joint white; tail Fuscous dorsally, whitish ventrally.

Fresh subadult pelage (place and date as above). As described above, but upper parts much duller, the mass near Hair Brown, becoming Drab on the sides; buffy bands Pinkish Buff; tail slightly darker ventrally than in adult pelage, nevertheless paler ventrally than dorsally.

Measurements.—Averages and extremes in millimeters of 20 specimens from the Sierra San Carlos: Total length, 217 (204–232); length of tail, 113 (104–123); length of hind foot, 22 (20–23); ear (from notch, fresh) 19 (17–20). Greatest length of cranium, 28.2 (27.5–29.4); zygomatic breadth, 13.7 (13.3–14.2); length of rostrum (from notch adjoining lachrymal on superior, inner border of zygomatic process of maxilla to tip of nasal on same side of skull), 10.6 (10.2–11.2); length of posterior part of cranium (in a straight line mid-dorsally from fronto-parietal junction to superior lip of foramen magnum), 11.1 (10.5–11.9); length of interparietal (measured on mid-line, excluding attenuations), 3.3 (2.9–4.0); alveolar length of molar row, 4.1 (3.8–4.4). Number of caudal scales on dorsal stripe in third centimeter from base of tail, 22 (20–25).

Remarks.—*P. p. collinus* is an inhabitant of rocky and brush-covered foothills. In Tamaulipas it lives in a vegetational belt that is situated altitudinally below oak and pine forests and above the generally open and short vegetation of the coastal plains. This foothills belt is characterized by tall, thorny shrubs (Dice, *op. cit.*). Trapping records suggest that the form is more common in fairly open situations than in dense thickets. Specimens from the Sierra San Carlos were collected in the following situations: At San José, on limestone slopes covered with lechuguilla (*Agave lechuguilla*), maguey (*Agave* sp.) and low brush; among granjeno (*Celtis pallida*), other thorny shrubs and prickly pear (*Opuntia* sp.). At Tamaulipeca, in a limestone outcrop covered with lechuguilla; in a thicket of cenizo (*Leucophyllum texanum*) and thorny shrubs. In the lower part of the oak zone at La Vegonia mine, *P. pectoralis* was uncommon while *P. boylei* was abundant. *P. boylei* was not found at any other collecting station in the Sierra San Carlos, or if so, no specimens were preserved. The specimen from the vicinity of Acuña was trapped in "brushy grassland," to quote directly from the specimen label.

Some of the specimens at hand suggest that *collinus* intergrades with *eremicoides* in the foothills and low-lying valleys of the Sierra Madre Oriental. Examples from the vicinity of Monterrey average smaller than topotypes of *collinus;* the two series are indistinguishable in color of upper parts and of tarsi. Six specimens from Santa Catarina are distinctly paler dorsally than those from Monterrey; their tarsi are also paler. Although intermediate in coloration they clearly resemble *eremicoides* more than they do *collinus* in coloration and

cranial size. The same can be said of two specimens from Miquihauna. They, too, are intermediate in coloration, but are clearly referable to *eremicoides*. The examples from Santa Catarina and Miquihuana also appear to be smaller in length of body than those from localities to the east, however, they, and the examples from Monterrey and Cerro de la Silla as well, lack external measurements. The three specimens from Jaumave likewise have paler upper parts and tarsi than the examples from the more eastern localities. Two of the specimens resemble topotypical *collinus* in size of body, hind foot, and skull. The third is no larger than a specimen of *eremicoides* from northeastern Durango.

Specimens examined.—Thirty-five from the following localities in México: (Specimens indicated by the symbol U.S. are contained in the collections of the Fish and Wildlife Service.) *Nuevo León:* Monterrey, 5 (U.S.); Cerro de la Silla, 1 (U.S.). *Tamaulipas:* near Jaumave, 2400 ft., 3; Sierra San Carlos, 21 (Marmolejo, 1700 ft. 4; San José, 2000 ft., 14; Tamaulipeca, 1500 ft., 1; La Vegonia mine, 2900 ft., 2); Sierra de Tamaulipas, near Acuña, 1600 ft., 1; Ciudad Victoria, 1100 ft., 2 (U.S.); Villagran, 1300 ft., 2.

DISCUSSION

External and cranial proportions of P. boylei and P. pectoralis.—In the analysis which led to the description of *collinus*, the possibility was explored that *collinus* is morphologically more similar to *P. boylei* than to *P. pectoralis*. Early in the study it was evident that both forms represented in the series from the Sierra San Carlos belong in the *P. boylei* group, as the group is outlined by Osgood (N. Amer. Fauna, 28, 1909). It was equally clear that diagnostic characters of *P. pectoralis* are to be seen in the series of *collinus*, while the characters of the other form are predominantly those of *P. boylei*. Body and cranial size, however, did not seem to fit with the other characters. Length of body and, especially, of cranium in the samples of *collinus* greatly exceed those in the sample of *P. boylei*. Such a size relationship does not obtain in any other area where both species are found, to my knowledge. In other parts of their ranges where the two species are sympatric, *pectoralis* is always the smaller of the two. Moreover, on the highlands of central México, at least, the differences between *P. boylei* and *P. pectoralis* in cranial length and in body length are roughly equivalent to the differences in size between the two forms in the Sierra San Carlos. But in the Sierra San Carlos the form that is otherwise like *P. pectoralis* is larger, rather than smaller, than the race of *P. boylei*. This apparent reversal in size relationships made it essential that the samples from the Sierra be compared in detail with samples of *P. boylei* and *P. pectoralis* from other parts of their ranges.

To determine whether the characters of *collinus* as a whole were more like those of *P. boylei* or those of *P. pectoralis*, I employed a method of graphic analysis described by Simpson (Amer. Mus. Novitates, 1136, 1941). This method utilizes a series of ratio diagrams in which any one variant is related to other variants of the same or any other sample. In these diagrams external and cranial proportions observed in one sample are readily compared with proportions in other samples. A curve may be constructed for each sample. If the animals of any two samples have identical proportions in the parts measured then the curves of those samples will coincide in slope. If they are identical in absolute size as well as in proportions then their curves will coincide in position as well as in slope.

The procedure in preparing the ratio diagram shown as Figure 1 is as follows: Six measureable, diagnostic variants were selected. A mean was calculated for

each variant of each sample. The samples consist of six series of *P. boylei* from various parts of the range of the species, of series of *P. pectoralis* from three different localities, and of the sample of *collinus* from the Sierra San Carlos. The means were converted to logarithms. The logs of the six means for the sample of *P. boylei levipes* from Amoles, Querétaro, were then plotted in a vertical line on graph paper. The vertical line represents zero difference on a horizontal scale along which positive and negative differences are indicated to three decimal places. The points on the vertical line represent the standard to which other samples are related. The amount that the log of each measurement differs from the Amoles sample was then plotted. Finally, for each variant, means of the five samples of *P. boylei*, excluding the standard series, and means of the three series of *P. pectoralis*, excluding the sample of *collinus*, were calculated and the differences between their logs and the standard were determined and plotted. Lines connecting those plotted points indicate sample estimates of proportions obtaining in each species. The samples and number of specimens employed in Figure 1 are as follows: *P. boylei levipes:* Amoles, Querétaro, 20; Acuña, Sierra de Tamaulipas, Tamaulipas, 16; La Vegonia, Sierra San Carlos, Tamaulipas, 14. *P. b. spicilegus:* Santa Isabel, Nayarit, 20. *P. b. rowleyi:* Huachuca Mountains, Arizona, 9; Valencia County, New Mexico, 8. *P. pectoralis pectoralis:* Toliman, Querétaro, 15; San Agustín, Hidalgo, 7; Ixtlán del Río, Nayarit, 10. *P. p. collinus:* Sierra San Carlos, Tamaulipas, 20.

In Figure 1 each series of *P. boylei* resembles the standard series, also a sample of *P. boylei*. Their proportions cluster about the standard, falling approximately in a vertical line near it. The proportions of the series of *pectoralis* likewise are similar to one another, but they are dissimilar to those of *boylei*. Their points on the diagram are closely aligned, but they lie on a diagonal line rather than on a vertical line. It is clear that with respect to *boylei*, *pectoralis* has more caudal scales per centimeter, is similar to *boylei* in length of tail and length of posterior part of the cranium, but has a shorter cranium, smaller zygomatic diameter, shorter rostrum, and shorter molar row. In addition, *pectoralis* has a shorter cranium, relative to tail length and to number of caudal scales, than does *boylei*, but the cranium is about the same length relative to zygomatic breadth; the rostrum is shorter relative to length of the posterior part of the cranium, to greatest length of cranium, and to zygomatic breadth, but is longer relative to length of molar row. Other differences in proportions between the species are indicated in the graph.

The proportions of *collinus* fit with those of the samples of *P. pectoralis*. The series of points representing *collinus* do not approximate the vertical line of *boylei*. They parallel those of *pectoralis*, but, except for caudal scalation, they are consistently displaced to the right. It follows, therefore, that as sampled here *collinus* is larger than *pectoralis*, but is quite similar to it in proportions. It is generally dissimilar to *boylei*.

Status of populations in Texas.—A problem related to the foregoing one, concerning the identity of the populations of the Sierra San Carlos, has also received attention. It pertains to populations of the *P. boylei* group of species in western

Texas. The University of Michigan Museum of Zoology contains 58 specimens of this species group from the Chisos and Davis mountains. In the years that they have been on deposit in the Museum some of those specimens at various times have been labeled and relabeled *Peromyscus boylei rowleyi* or *P. pectoralis laceianus*. I wanted to know the correct identity of those specimens. Ratio diagrams were prepared for them. The results were confusing. Instead of the clear-cut patterns, one of *boylei* and another of *pectoralis*, as seen in Figure 1, the series of

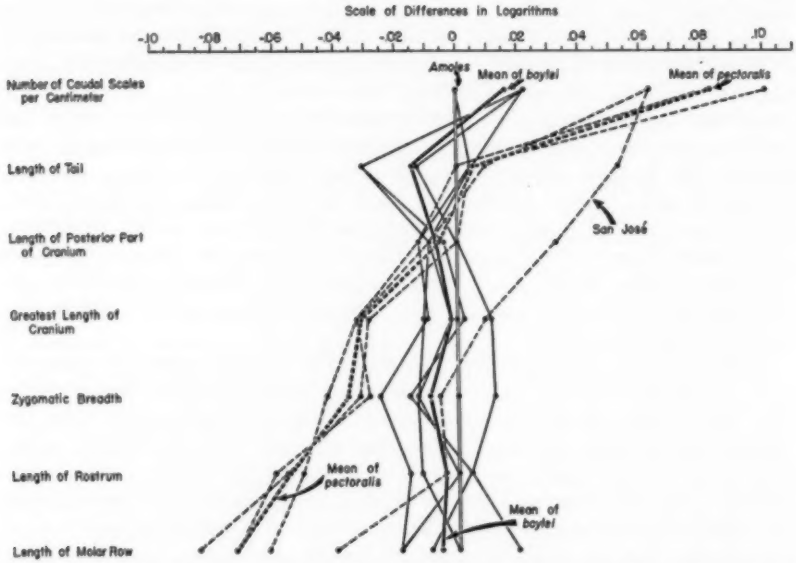

FIG. 1.—Ratio diagram comparing 7 dimensions of skin and skull in 6 samples of *Peromyscus boylei* (solid lines) and 4 samples of *P. pectoralis* (broken lines). For explanation see text.

points are intermixed, with little indication that two species with proportions as in Figure 1 are represented. Some of the specimens clearly resemble *boylei* in one or two variates, but they are proportioned as in *pectoralis* in other characters. Other examples are intermediate in one or more of the variates.

Since those results were inconclusive, I next employed series from various localities in the southern United States. These were divided into two groups on the basis of color of tarsi. Color of the tarsi has been considered of prime importance in distinguishing the species *boylei* and *pectoralis* in the United States (Osgood, *op. cit.*). Specimens with dusky tarsi comprise one group; whitish tarsi characterize the other group. The two categories are more discrete in theory than they are in practice; all stages of intermediacy actually are represented in the series. The localities and number of items in each group follow: *Dark tarsi:* Hua-

chuca Mountains, Arizona, 9; Valencia County, New Mexico, 8; Guadalupe Mountains, Texas, 16; Davis Mountains, Texas, 25; Kerr County, Texas, 9; Adair County, Oklahoma, 9. *Pale tarsi:* Chisos Mountains, Texas, 16; Davis Mountains, Texas, 5; Guadalupe Mountains, Texas, 12; Kerr County, Texas, 15. The specimens from the Guadalupe Mountains and from Kerr County, the latter essentially topotypes of *P. b. attwateri* and *P. p. laceianus*, were kindly sent on loan from Texas A. and M. College.

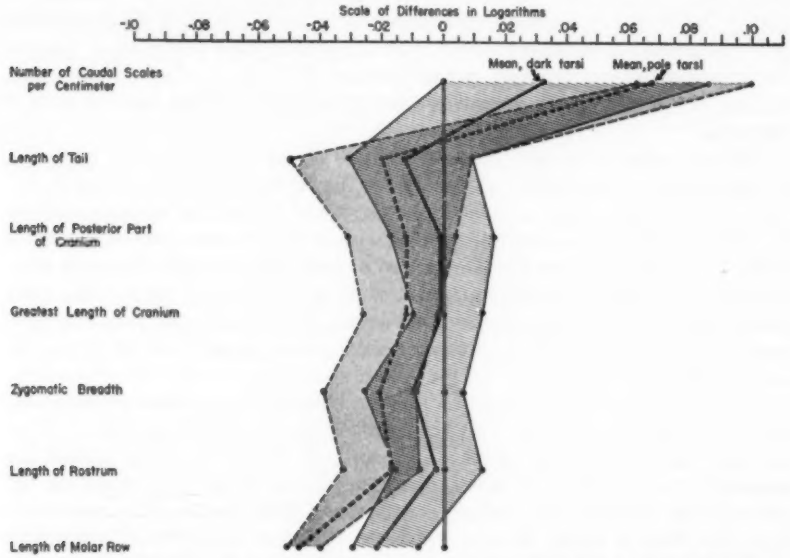

FIG. 2.—Ratio diagram comparing 7 dimensions of skin and skull in 11 samples of the *Peromyscus boylei* species group. Seven samples are characterized by dusky tarsi. Their mean differences from the standard (vertical line) lie within the shaded area; grand mean differences for the 7 samples are indicated by the heavy line. In 4 samples the tarsi are pale. Their mean differences fall within the stippled area and their grand mean differences are indicated by the heavy broken line.

In the diagram prepared for these samples the series of points tend to group about the standard or to lie between those of *boylei* and *pectoralis* as seen in Figure 1. All samples, those with white tarsi and dark tarsi alike, trend toward *pectoralis* in number of caudal scales and in length of molar row. In other proportions they are like *boylei*. In both the pale-tarsi group and the dark-tarsi group there is considerable variation, but mean lines of the two groups are roughly parallel (Fig. 2). Both lines approximate the vertical line of *boylei*.

Two important points are raised by this analysis. First, the samples of undoubted *P. boylei* from México, Arizona, and New Mexico differ from one another somewhat in size and in proportions. Some of the differences are recognized in

distinguishing races of that species. Notwithstanding those differences, all of the samples of *P. boylei* are strikingly similar in proportions. The same is true of the series of *P. pectoralis*. Geographic variations in size and proportions are apparent, but they do not obliterate a morphological pattern that is characteristic of all samples of the species and that differs from the pattern of *boylei*.

Secondly, the identity of the populations from Texas is open to question. The series at hand includes specimens with white tarsi and others with dark tarsi from the vicinity of the type localities of *P. b. attwateri* and *P. p. laceianus*. If both *P. boylei* and *P. pectoralis* are represented in my series, then the proportions of *P. pectoralis* are markedly different in Texas than they are in other regions. Or, if proportions of the two species contrast in Texas as they do elsewhere, specimens from that state cannot be correctly identified on the basis of color of the tarsi.

I do not intend that only one form, whether of the species *boylei* or *pectoralis*, is represented in the series from Texas. On the contrary, the data suggest that two forms may be present, at least in the Davis and Guadalupe mountains and in Kerr County where both pale and dark tarsi occur. In the series from each of those areas the group of specimens characterized by pale tarsi averages smaller in most external and cranial dimensions and in that group there are, on the average, more caudal annulations per centimeter of tail length. At each of these localities, then, there may be two forms, these distinguishable by size, count of caudal scales, and color of tarsi.

The data do cause one to question whether either of those forms is conspecific with *P. pectoralis* of México. The body proportions of the two groups in Texas are strikingly similar. Although the proportions in each of those groups are somewhat between those of *boylei* and *pectoralis*, as those proportions are observed in the samples from México, Arizona, and New Mexico, they are clearly more like those of *boylei*. It seems probable, therefore, that either *P. pectoralis* and *P. boylei* interbreed in Texas, or that the white- and dark-tarsi groups represent closely related forms both of which are more similar to *P. boylei* than to *P. pectoralis*. The possibility that both *attwateri* and *laceianus* are races of *P. boylei* will bear investigation.

That the relationships of the two forms of the *Peromyscus boylei* group in western Texas is unclear has already been pointed out by Blair (Tex. Jour. Sci., 1: 17, 1949). He, too, found that specimens from the region were intermediate in some characters between the forms currently known as *P. b. attwateri* and *P. p. laceianus*. In order to understand the relationships of the forms a detailed study is needed which is based on precise ecological data and adequate series of specimens from many selected localities in Texas.

Museum of Zoology, University of Michigan, Ann Arbor. Received January 9, 1952.

GENERAL NOTES

A NEW *BASSARISCUS* FROM THE UPPER PLIOCENE OF KANSAS

The University of Michigan Museum of Paleontology field party spent the summer of 1951 working the late Cenozoic deposits in southwestern Kansas and northwestern Oklahoma. The party consisted of Thomas M. Oelrich, Clyde O. Priddy, Alex F. Ricciardelli, John C. Wagner, Faye Ganfield Hibbard, and Claude W. Hibbard.

While checking the exposures at the type locality of the Rexroad formation in Meade County, Kansas, a pocket of flour-sand, recently exposed by erosion, was found to contain numerous bone fragments, isolated teeth, and part of the right ramus and a fragmentary piece of the left maxillary of a *Bassariscus* which differs from those of other known species.

Bassariscus casei, sp. nov.

Holotype.—No. 29169, University of Michigan, Museum of Paleontology, right ramus bearing canine, alveoli of P_1 and P_3; P_3, P_4-M_2 present; also, part of the left maxillary bearing the posterior part of P^3, P^4, M^1 and alveoli of M^2. Collected in the summer of 1951 by the University of Michigan Museum of Paleontology field party.

Horizon and type locality.—Upper Pliocene, Rexroad formation, Rexroad fauna (Hibbard, 1950). Locality no. 3, W½ SW¼ sec. 22, T.33S., R.29W., Meade County, Kansas.

Diagnosis.—A *Bassariscus* the size of *B. astutus* (Lichtenstein) with the paraconid and protoconid, also the protoconid and metaconid, separated by wider valleys between these cusps than in the Recent species. The hypoconid and entoconid are not as well developed as in *B. astutus*. The paraconid of M_2 is better developed and more centrally located on the anterior face of M_2 than in *B. astutus*. P^4 is distinct in that a well-developed cingulum extends from the hypocone to the base of the metacone, producing a distinct shelf on the inner side of the tooth, a condition not present in *B. astutus* although a less prominent shelf is present in *Bassariscus sumichrasti* (Saussure).

Description of holotype.—The holotype is a right ramus and part of the maxillary of an adult animal (Fig. 1). The anterior tip of the ramus with the incisors is missing. The teeth of the lower premolar series are uncrowded. A diastema as long as in Recent specimens separates the canine and P_1. P_1 is missing, though single rooted. P_2 is narrower posteriorly than it is in *astutus*. P_3 is missing. The paraconid of P_4 is not as well developed as in *astutus*. The carnassial notch between the paraconid and protoconid is open. The valley between the protoconid and metaconid is open. The hypoconid, hypoconulid, and entoconid are distinct cusps though they are not as high and well developed as in *B. astutus*. The paraconid of M_2 is located centrally in the anterior face of the tooth in a direct line with the open valley between the metaconid and protoconid. The lower tooth series of *B. casei* has an anteroposterior length equal to that of *B. astutus arizonensis* Goldman, though all of the teeth are slightly narrower in transverse width, and possess broader open valleys between the cusps. The posterior mental foramen is situated beneath P_3. The anterior mental foramen is much larger and occurs beneath the anterior root of P_2. The coronoid fossa is deeper and narrower anteriorly than in Recent specimens examined.

The left maxillary is broken anteriorly through the midline of P^3 and only the posterior border of the infraorbital foramen is present. The position and shape of the foramen appears to have been the same as in *Bassariscus astutus*. P^4 is distinct in that a well-developed cingulum extends from the protocone to the metacone in a nearly straight line along the base of the tooth, therefore, producing a prominent shelf. Posterior to the protocone is the hypocone. The cingulum is only slightly indented posterior to the hypocone in contrast to the deep indentation posterior to the hypocone in *B. astutus*. The parastyle and protocone are not as high as in the Recent species. The carnassial notch between the paracone and metacone is open. M^1 has the shape of M^1 in Recent species. A very small protoconule is present. The hypocone is more distinctly separated from the protocone and metacone than in *B. astutus*. There is a distinct basal cingulum along the anterior base of the protocone

and protoconule. This cingulum is better developed than it is in *B. sumichrasti*. Alveoli of M^2 are present.

Measurements in millimeters of holotype.—No. 29169 UMMP. Length from posterior border of alveolus for canine to posterior border of M_2, 28.2; length of P_4 to M_2, inclusive, 16.5; length of P_2, 3.5; width of P_2, 1.5; length of P_4, 4.8; length of M_1, 7.4; width at trigonid, 3.5; length of trigonid, 4.8; length of talonid, 2.6; width at talonid, 2.7; ratio, length of talonid of M_1 to length of trigonid of M_1, 54.1; length of M_2, 5.1; greatest width of M_2, 2.9; greatest anteroposterior length of P^4, 7.0; greatest transverse width of P^4, 4.4; greatest anteroposterior length of M^1, 4.9; greatest transverse width of M^1, 7.5.

Remarks.—*Bassariscus casei* is distinguished from the Recent species by its narrower lower premolars and molars; by the more open valleys between the cusps; and, also, by the

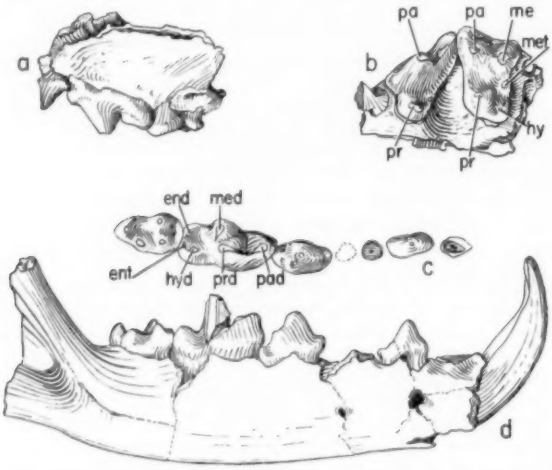

FIG. 1.—*Bassariscus casei*, sp. nov.; holotype, UMMP No. 29169. (a and b) Left maxillary with P^4–M^1, lateral and ventral views. (c and d) Occlusal view of RP_2, P_4–M_2, and lateral view of right ramus. All ×2. Drawing by Jane S. Mengel.

well-developed internal cingulum of P^4. *B. casei* is more closely related to *B. astutus* than to *B. sumichrasti*. No characters were observed that would prevent *B. casei* from being in a direct phylogenetic line with *B. astutus*.

Bassariscus casei is distinguished from *B. antiquus* Matthew and Cook by the ratio of the length of the talonid to the length of the trigonid of M_1; 54.1 in *B. casei*, more than 70 in *B. antiquus*. It is distinguished from *B. parvus* Hall by the lack of a crowded premolar series in the lower jaw and the presence of a hypocone on P^4, also by the relationship of P^4 to M^1, where the metacone of P^4 joins the anterior face of M^1 at a more acute angle. For a detailed discussion of these two Miocene species see Hall (1927) and Gregory and Downs (1951).

Bassariscus ogallalae Hibbard is distinguished by having equal anteroposterior lengths for M_1 and M_2. *B. ogallalae* was described as having been taken from a Lower Pliocene deposit (Hibbard, 1933). It was taken from a Middle Pliocene deposit at the type locality of the Ogallala formation.

Bassariscus casei is distinct from *B. rexroadensis* Hibbard (1959), although both are members of the Rexroad fauna and were taken in Meade County, Kansas. *B. rexroadensis* is known only from the type, a left M_1. The M_1 has an anteroposterior length of 8.5 mm.;

the width of the tooth is 4.4 mm. The base of the valley between the metaconid and protoconid is closed as in Recent species. The position of the hypoconulid is a distinctive character of this form. It occurs posterior and medial to the hypoconid instead of medial to the hypoconid and entoconid as in *B. casei* and Recent species. A well-developed notch separates the hypoconulid and entoconid. On the basis of the characters of M_1, *B. casei* is more closely related to *B. astutus* than to *B. rexroadensis*. There is certainly more than a time factor involved in regard to the relationship of the two species from the Rexroad fauna.

Bassariscus casei differs from *B. sonoitensis* Skinner (1942), from the late Pleistocene of Arizona, by its less rectangular M^1 and by the more acute angle formed by the posterior junction of P^4 with the anterior face of M^1.

Bassariscus casei has been compared with six adult specimens of *B. astutus arizonensis* from Pima County, Arizona. One of these specimens, an adult male, No. 63905 UMMZ, lacks both first premolars. The other premolars are slightly larger than those in a normal series. Comparison was also made with one adult of *B. astutus* from Brisco County, Texas, and one specimen of *B. s. notinus* Thomas, from Costa Rica. All of the Recent specimens are in the Museum of Zoology, University of Michigan. The illustrations were made possible by the financial support of the Faculty Research Fund of the University of Michigan.

This species is named for Dr. E. C. Case who began his work in vertebrate paleontology in the High Plains Region and who has kindly given helpful criticisms and suggestions in the study of the High Plains Cenozoic faunas.

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Claude W. Hibbard, *Museum of Paleontology, University of Michigan, Ann Arbor, Michigan.* *Received November 3, 1951.*

THREE NEW MAMMALS FROM SOUTHERN FLORIDA

Studies on the mammalian fauna of southern Florida have revealed the presence of two previously unrecognized races of cotton mice and of one mole. The writer wishes to acknowledge with thanks the courtesy extended by C. C. Sanborn of the Chicago Natural History Museum, Miss Barbara Lawrence of the Museum of Comparative Zoology, Stanley P. Young of the U. S. Fish and Wildlife Service, and H. B. Sherman of the University of Florida for loan of specimens in their collections. Descriptions of the new races are herewith given.

Scalopus aquaticus porteri, subsp. nov.

Type.—Adult female, skin and skull, no. 97718, Museum of Zoology, University of Michigan; from Uleta, Dade County, Florida; taken by Albert Schwartz, 31 August 1951. Original number 1999.

Distribution.—Known only from Uleta and Biscayne Gardens, Dade County, Florida, but probably occurs along the east coast of the Florida Penninsula south of Jupiter and Hypoluxo.

Diagnosis.—Similar to *S. a. bassi* from Englewood, Sarasota County, but darker. Skull similar to that of *bassi*, but with flatter and broader brain case, less inflated rostrum, and

weaker dentition. Differs from both *S. a. parvus* and *S. a. australis* from peninsular Florida in much smaller size, smaller skull, and darker coloration.

Description of type.—External measurements; total length, 120 mm.; tail, 15; hind foot, 14. Cranial measurements (as taken by Jackson, N. A. Fauna No. 38: 19, 1915): greatest length, 28.4; mastoidal breadth, 14.5; interorbital breadth, 6.5; palatilar length, 11.6; maxillary tooth row, 9.0.

Characters and comparisons.—As indicated above, *S. a. porteri* differs markedly from the two more northern races of moles, *parvus* and *australis*, from the Florida Peninsula in its smaller size and darker coloration. From *S. a. bassi*, which occurs along the west coast of Florida at Englewood and Fort Myers, *porteri* differs in darker color (Clove Brown of Ridgway, Color Standards and Color Nomenclature, 1912); topotypes of *bassi* are between Bister and Snuff Brown of Ridgway. The venter is similar in color to the dorsum, and a light yellowish wash occurs over the breast. In specimens of *bassi* there is a tuft of orange hairs at the wrist; this tuft is absent in *porteri*.

External measurements (in millimeters) of a male from Biscayne Gardens, Dade County, are: total length, 130; tail, 20; hind foot, 16. External measurements of a female from the same locality are: total length, 118; tail, 18; hind foot, 16. Cranial measurements of the above male and female, respectively, are: greatest length, 27.9, 27.8; mastoidal breadth, 14.6, 14.4; interorbital breadth, 6.5, 6.4; palatilar length, 11.5, 11.3; maxillary tooth row, 8.7, 9.1. External measurements of four male *bassi* (topotypes), average and extremes: total length, 111 (105–115); tail, 17 (16–18); hind foot, 15 (15–16). Cranial measurements of the same series of *bassi*: greatest length, 28.1 (28.0–28.5); mastoidal breadth, 14.7 (14.5–14.9); interorbital breadth, 6.4 (6.3–6.7); palatilar length, 11.6 (11.1–12.8); maxillary tooth row, 8.7 (8.2–9.1). External measurements of the type of *bassi*: total length, 115; tail, 17; hind foot, 15. Cranial measurements of the type: greatest length, 26.3; mastoidal breadth, 13.4; interorbital breadth, 6.2; palatilar length, 10.3; maxillary tooth row, 8.3.

Comparison of the above measurements of *S. a. bassi* and *S. a. porteri* indicates that the latter is larger in total length, but equals or only slightly exceeds *bassi* in length of tail and hind foot. The two females of *porteri* are larger in all cranial measurements than the single available female of *bassi*. The male *porteri* is smaller, in greatest length and mastoidal breadth, than any of the four topotypical *bassi* males, and the length of the tooth row is at the upper limit of the *bassi* tooth row measurements.

The skulls of *bassi* resemble those of *porteri* closely, but are longer and have less expanded brain cases. The skull of *porteri* generally appears stockier, with a relatively shorter and less inflated rostrum. The dentition of the two races is markedly different. The upper incisors, canines, and premolars of *porteri* are noticeably weaker than those of *bassi*, even though the length of the tooth row of *porteri* is somewhat greater.

Remarks.—A single specimen from Jupiter, Martin County, Florida, and a specimen from Hypoluxo, Palm Beach County, are probably intergrades between *S. a. australis* and *S. a. porteri*. The specimen from Hypoluxo (Biol. Survey Coll. 16579/23510) is an immature animal, of small size, without external measurements; the skull resembles those of the series of *porteri* very closely, but the pelage color is much lighter, resembling the color of a series of *australis* from Oak Lodge, Brevard County. The specimen from Jupiter (C.N.H.M. 15102) is paler than the type of *porteri* and paler also than *bassi*, and resembles topotypes of *australis* from Gainesville. It is probable that these two specimens show the beginning of intergradation between *australis* and *porteri* along the east coast, since both have small skulls which are close to *porteri*, but have coloration typical of *australis*.

The ranges of *S. a. bassi* and *S. a. porteri*, the two southernmost races of moles in the eastern United States, are separated by the intervening Everglades; both *bassi* and *porteri* are small forms which are more or less coastal in distribution and represent extremes in small size in the southeast, on the west and east coasts of the Florida Peninsula, respectively.

Jackson (*op. cit.*: 39) assigns a specimen from Lemon City, Dade County, to *S. a. australis*, but comments on its smaller size and darker color. This specimen is an alcoholic, and no cranial measurements or color data are available. Presumably this specimen may be referred to *porteri*.

The writer takes great pleasure in naming this new race of *Scalopus* for Raymond P. Porter, whose co-operation with the studies on the mammals of southern Florida has been of the utmost importance.

Specimens examined.—Sixty five, all from Florida, as follows: *Scalopus a. australis:* Alachua Co., Gainesville, 22; 6 miles east Gainesville, 1; 3 miles north Gainesville, 4; Levy Lake, 1; Alachua Co., 2. Putnam Co., Welaka, 1. Brevard Co., Oak Lodge, 10. Seminole Co., Lake Harney, 2. Duval Co., Jacksonville, 1. Baker Co., Glen St. Mary, 1. *Scalopus a. parvus:* Levy Co., 9 mi. NE Cedar Key, 2; 6 mi. SW Otter Creek P.O., 1. Pasco Co., New Port Richey, 1. Marion Co., Silver Springs, 1. Manatee Co., Bradenton, 2; Palmetto, 2. *Scalopus a. bassi:* Sarasota Co., Englewood, 6. *Scalopus a. porteri:* Dade Co., Uleta, 1; Biscayne Gardens, 2. Possible intergrades between *S. a. australis* and *S. a. porteri:* Martin Co., Jupiter, 1. Palm Beach Co., Hypoluxo, 1.

Peromyscus gossypinus allapaticola, subsp. nov.

Type.—Adult female, skin and skull, no. 97721, Museum of Zoology, University of Michigan; from 12 miles northeast of Rock Harbor, on Key Largo, Monroe County, Florida; taken by Albert Schwartz, 28 December 1950. Original number 1608.

Distribution.—Known only from Key Largo, Monroe County, Florida.

Diagnosis.—A large reddish cotton mouse, larger than either *P. g. palmarius* or *P. g. restrictus*, of the Florida Peninsula, in measurements of total length and tail. Dorsum brighter than that of either *palmarius* or *restrictus* and somewhat less overlaid with black on the mid-dorsal line, sides with distinctive grizzled appearance. Compared with *palmarius*, skull is larger in greatest length, basilar length, zygomatic breadth, interorbital breadth, length of palate, and upper tooth row; it exceeds *restrictus* in measurements of greatest length and upper tooth row.

Description of type.—External measurements: total length, 178 mm.; tail, 74; hind foot, 23; ear from notch, 19. Cranial measurements (as taken by Osgood, N. A. Fauna No. 28: 22–23, 1909): greatest length, 28.8 mm.; basilar length, 21.6; zygomatic breadth, 14.7; interorbital constriction, 4.9; nasals, 11.1; shelf of bony palate, 4.5; palatine slits, 5.2; diastema, 7.1; maxillary tooth row, 4.2. Color: dorsal coloration between Sayal Brown and Hazel (Ridgway, *loc. cit.*), very lightly overlaid with black along mid-dorsal area; crown Sayal Brown; sides and cheeks clear Sayal Brown, not overlaid with black; venter white, with Cinnamon Buff wash on throat and chest; dorsal and ventral coloration sharply separate with no decrease of brightness of dorsal color along lateral line; feet white; ankles dusky; tail bicolor, brown above, white below.

Characters and comparisons.—*Peromyscus g. allapaticola* is an insular form of the cotton mouse. The race differs from *palmarius* and *restrictus* in the following characters. Coloration: the general appearance of *allapaticola* is reddish, that of *palmarius* (as known from ten topotypes from Oak Lodge, Brevard County, Florida) is yellowish, and that of *restrictus* (as known from six topotypes from Chadwick Beach, Charlotte County, Florida) is pinkish cinnamon. A series of 21 specimens from the type locality of *allapaticola* agrees in color with the type. Old adults especially show the reddish coloration, while young adults are Tawny Olive. Old adults taken in December and February have the distinctive reddish pelage, which varies between Sayal Brown and Snuff Brown. Even in the young adult pelage, the coat is more reddish than that of *palmarius*. Compared with adult specimens of *restrictus*, *allapaticola* is brighter and more reddish; the coat of *restrictus* is pinkish cinnamon and seems more washed with gray.

External measurements (average and extremes in millimeters) of a series of seven male and five female adults from Key Largo are: total length, 179 (170–189); tail, 77 (72–87); hind foot, 21 (21–23); ear from notch, 18 (16–20). Cranial measurements of the same series are: greatest length, 28.3 (27.2–29.2); basilar length, 21.5 (20.2–22.7); zygomatic breadth, 14.1 (13.8–14.7); interorbital constriction, 4.5 (4.2–5.0); nasals, 10.5 (9.8–11.6); shelf of bony palate, 4.5 (4.1–5.1); palatine slits, 5.1 (4.5–5.4); diastema, 6.9 (6.3–7.4); maxillary tooth row, 4.0 (3.8–5.4). Comparison of these data with measurements of three male and seven female adult topotypes of *palmarius* shows that *allapaticola* exceeds the former in all

measurements except length of nasals, which are shorter in *allapaticola*, and in length of hind foot, palatine slits, and diastema, which are equal in *allapaticola* and *palmarius*. Measurements of *allapaticola*, compared with those of seven adults given by Howell (Jour. Mamm., 20: 365, 1939) in the original description of *P. g. restrictus*, indicate that *allapaticola* exceeds *restrictus* in total length, tail, ear, greatest length, and upper tooth row, but that the nasals of *allapaticola* are shorter. Skulls of *allapaticola* and *restrictus* are equal in measurements of zygomatic breadth and interorbital constriction.

Remarks.—That *allapaticola* is a well-marked insular race of the cotton mouse is shown by its large size and bright coloration. Although direct contact with mice on the Florida mainland is relatively unlikely, specimens from the southern counties of Florida along the east coast begin to show the reddish coloration which is typical of *allapaticola*. However, in none does it reach the extreme found in the insular form. Two specimens recorded by Osgood (*op. cit.*, p. 140) from Planter, Key Largo, presumably are to be assigned to this race.

The source of the subspecific name is 'allapattah,' the Seminole word for the dense jungle-like stands of hardwood trees, which are called hammocks, in southern Florida. Since the insular cotton mice occur in greatest abundance in the dense hammock at the northern end of Key Largo, this seems a fitting designation for this brightly-colored form.

Specimens examined.—Thirty eight from Florida, as follows: *Peromyscus g. palmarius:* BREVARD CO., Oak Lodge, 11. *Peromyscus g. restrictus:* CHARLOTTE CO., Chadwick Beach, 6. *Peromyscus g. allapaticola:* MONROE CO., 12 mi. NE Rock Harbor, Key Largo, 21.

Peromyscus gossypinus telmaphilus, subsp. nov.

Type.—Adult male, skin and skull, no. 97728, Museum of Zoology, University of Michigan; from Royal Palm Hammock, Collier County, Florida; taken by Albert Schwartz, 4 April 1951. Original number 1830.

Distribution.—Southwest portion of the Florida Peninsula, at least from Naples, Collier County, on the north, south and east to the vicinity of Monroe Station, Collier County, but not including the 10,000 Island region.

Diagnosis.—A small, brownish cotton mouse, smaller than *P. g. palmarius*, *restrictus*, or *allapaticola* from Florida. Dorsum darker than in these three races, more brownish, and generally strongly overlaid with black in the mid-dorsal area. Skull is smaller than or equal to that of *allapaticola*, *palmarius*, and *restrictus* in almost all measurements, except in having a greater zygomatic breadth than *palmarius* and a longer upper tooth row than either *palmarius* or *restrictus*.

Description of type.—External measurements: total length, 174 mm.; tail, 78; hind foot, 23; ear from notch, 18. Cranial measurements as taken by Osgood (*loc. cit.*): greatest length, 28.3 mm.; basilar length, 21.7; zygomatic breadth, 14.1; interorbital constriction, 4.4; nasals, 10.8; shelf of bony palate, 4.3; palatine slits, 4.3; diastema, 7.1; maxillary tooth row, 4.0. Color: dorsal coloration Sudan Brown (Ridgway, *op. cit.*), strongly overlaid with black along mid-dorsal line; crown Sudan Brown; sides and cheeks clear Antique Brown, which grades dorsally into Sudan Brown; ventral coloration grayish, with buffy wash along mid-ventral line; dorsal and ventral color clearly separate; feet whitish; ankles dusky; tail bicolor, blackish above, white below.

Characters and comparisons.—*P. g. telmaphilus* is a small, brownish cotton mouse which inhabits the southwest coast of the Florida Peninsula. The dark coloration is distinct, differing markedly from the reddish of *allapaticola*, the yellowish of *palmarius*, and the pinkish cinnamon of *restrictus*.

A series of 20 specimens from various localities listed below, referred to this race, agrees closely with the coloration of the type. All the specimens are brownish, distinguishing *telmaphilus* from the three other races, and all have a rather well-defined mid-dorsal band. In one specimen the dark dorsal coloration is admixed with gray, giving a somewhat 'dusted' appearance. The venter is either white or grayish in all specimens, and the pectoral spot may be present or absent; the mid-ventral buffy wash in the type does not occur in the remainder of the series in so marked a degree.

External measurements (average and extremes in millimeters) of ten adult males and five adult females from Collier County, Florida are: total length, 166 (152–189); tail, 71 (63–80); hind foot, 22 (21–23); ear from notch, 17 (16–18). Cranial measurements of the same series are: greatest length, 27.5 (26.1–30.1); basilar length, 20.6 (19.6–22.1); zygomatic breadth, 13.9 (13.2–14.6); interorbital constriction, 4.3 (4.1–4.6); nasals, 10.6 (10.1–11.7); shelf of bony palate, 4.2 (3.8–5.0); palatine slits, 4.9 (4.1–5.5); diastema, 6.5 (6.0–7.3); maxillary tooth row, 4.0 (3.8–4.2). Comparison of these measurements with those of a series of three male and seven female topotypes of *P. g. palmarius* indicates that *telmaphilus* exceeds *palmarius* in zygomatic breadth and maxillary tooth row, and measures less in total length, basilar length, nasals, palatine slits, and diastema. The remaining measurements are equal. From *restrictus*, *telmaphilus* differs in larger ear and longer tooth row, smaller total length, and shorter nasals, and equals *restrictus* in length of tail, hind foot, and greatest length of skull, zygomatic breadth, and interorbital constriction. Compared with *P. g. allapaticola*, *telmaphilus* is smaller in all external and cranial measurements, except that those of hind foot, nasals, and maxillary tooth row are regarded as equal.

Remarks.—Five skins and skulls from the Pinecrest Hammocks in Monroe County, Florida, show intergradation between *telmaphilus* and *palmarius* of the remainder of southern Florida. These specimens show the dark color of *telmaphilus* somewhat lightened with the reddish-yellow of *palmarius* as it occurs in southern Florida.

The subspecific name is derived from the Greek 'telme' for swamp. Specimens of this race were taken both in hammocks and swampy prairies, a rather unusual situation for cotton mice in southern Florida, and the name is an allusion to this peculiarity of habitat.

Specimens examined.—Sixty five from Florida, as follows: *Peromyscus g. palmarius:* Brevard Co., Oak Lodge, 11. *Peromyscus g. restrictus:* Charlotte Co., Chadwick Beach, 6. *Peromyscus g. allapaticola:* Monroe Co., 12 mi. NE Rock Harbor, Key Largo, 21. *Peromyscus g. telmaphilus:* Collier Co., Naples, 1; Royal Palm Hammock, 3; 4.3 mi. E Royal Palm Hammock, 1; 4.5 mi. E Royal Palm Hammock, 2; 6.2 mi. E Royal Palm Hammock, 1; Marco Island, 5; 1.7 mi. E Ochopee, 4; 8.6 mi. E Monroe Station, 3. Intergrades between *P. g. telmaphilus* and *P. g. palmarius:* Monroe Co., Pinecrest Hammock I, 4; Pinecrest Hammock II, 1; Pinecrest Hammock IV, 2.—Albert Schwartz, *Museum of Zoology, University of Michigan, Ann Arbor, Michigan.* *Received November 24, 1951.*

A BOTTLENOSE DOLPHIN FROM THE CALIFORNIA COAST

The dearth of specimen records in the literature of the bottlenose dolphin, *Tursiops gilli* Dall 1873, gives no indication of the abundance of this animal in the coastal waters of southern California. On many occasions while crossing from San Diego to Coronado on the ferry I have seen two or three of them. Dr. Carl L. Hubbs (MS) states that he has dozens of records of this species along the open coast of southern California, in San Diego Bay, and also down the coast of Baja California. Scammon's statement (Marine Mammals, 1874) that it occurs ". . . on the coasts of California and Mexico . . . likewise in the lagoons . . ." is an indication of its general distribution. Skeletal specimens of this mammal from southern California and Lower California are in several museums, among them the San Diego Museum of Natural History, the Museum of Vertebrate Zoology, and the U. S. National Museum. However, a mandible collected by Captain C. M. Scammon at Monterey, California, in 1897, and a specimen mentioned by Andrews (Bull. Amer. Mus. Nat. Hist., 30: 233–37, 1911) from the same locality constitute the only published records of specimens taken along the California coast.

On December 24, 1950, I found a male dolphin of this species, in an advanced state of decomposition, on Torrey Pines beach, within the city limits of San Diego, California. The animal is judged to be a young adult, since the teeth show little wear. The skull (Pl. I) was saved and is now deposited at the University of Washington. This specimen is ascribed to the species *gilli* on the basis of characteristics of the skull as observed by Dr. Henry W. Setzer and published by Mayer (Amer. Mid. Nat., 43: 183–85, 1950).

The following measurements (in mm.) are also expressed as thousandths of the base

lengths of body and skull, in parentheses after the respective measurements. External measurements: snout to base of tail notch, 2769; flipper length along leading edge, 381 (.138); height of dorsal fin, 283 (.102); width of flukes, span, 629 (.227). Skull measurements: maxi-

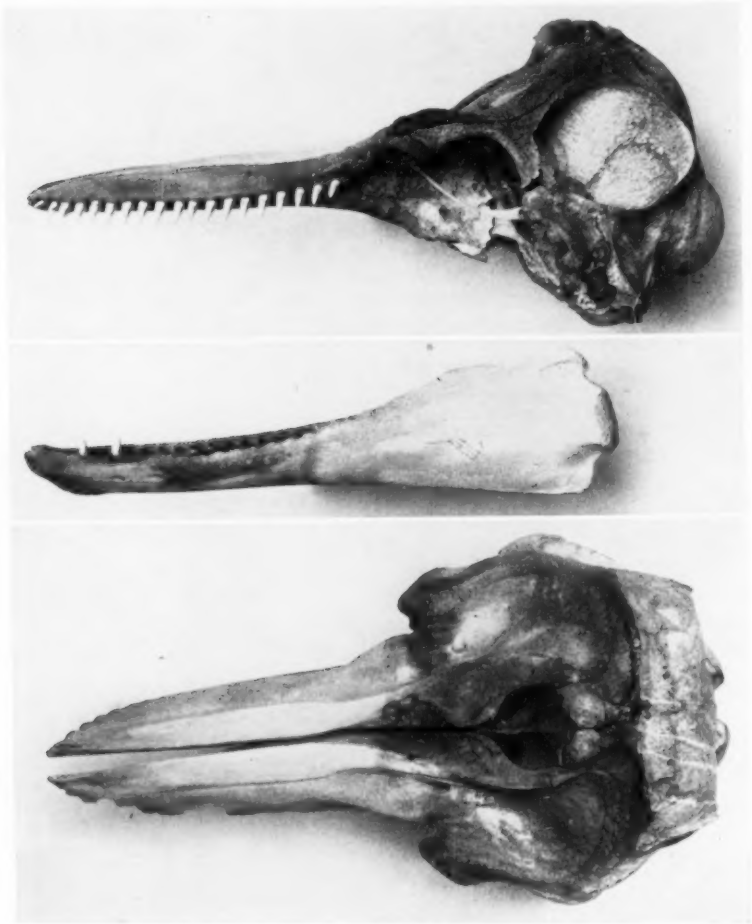

PLATE I

Skull of *Tursiops gilli*, lateral and dorsal views

mum length, condylobasal, 519; maximum length of rostrum from tip to line joining base of antorbital notches, 284 (.547); width of rostrum at base of antorbital notches, 136 (.262); maximum width, zygomatic, 274 (.528); width across postorbital process of supraorbital, 269 (.518); width of brain case across parietals, 200 (0.385); length of upper row of teeth to tip of mandible, right, 241, left, 242; length of lower row of teeth to tip of mandible, right, 250,

left, 248; maximum length of mandible, 437; maximum height of mandible through coronoid process, 107.

There were 19 teeth on the right side and 20 on the left side of the upper tooth rows; in the lowers, there were 21 plus three or four small alveoli on the right side and 19 plus three or four small alveoli on the left side.—KARL W. KENYON, *U. S. Fish and Wildlife Service, Seattle 2, Washington. Received May 21, 1951.*

NOTES ON A PREGNANT SEA OTTER

On May 31, 1951, a dead female sea otter, *Enhydra lutris nereis*, was found on the beach at China Cove, Point Lobos, Monterey County, California. The fur had slipped from a few regions of the carcass at the time it was found and the lips had been eaten away, possibly by crabs or gulls, but through the prompt action of Mr. R. A. Wilson, Warden of the Point Lobos State Park, the animal was frozen in a cold storage plant before decomposition advanced further. The specimen was a female in advanced pregnancy, and for this reason is of considerable importance.

Measurements in millimeters of the adult otter are: total length, 1206; tail, 279; hind foot, 203; ear from notch, 30; ear from crown, 20; weight, 48 pounds. The cause of death was not determined. Although there had been some bleeding into the abdominal cavity no bullet holes or other injuries were found. There was much subcutaneous and mesenteric fat. The stomach was empty, and the intestines contained about 20 acanthocephalans.

As in other Carnivora the uterus of the sea otter is bipartite. From the fusion of the two horns to the tip of the cervix measures 85 mm., and for the anterior 65 mm. of this distance the lumina of the two horns are separated by a membrane so that for only 20 mm. is there a common uterine and cervical canal. The chorio-allantoic, zonary placenta is a complete ring without marginal hematomae, but with a centrally situated, anti-mesometrial hematoma associated with a large bi-lobed sac projecting into the extra-embryonic coelom. The larger lobe of this sac has a capacity of more than 100 cc., although it actually contains little material, in this specimen a small quantity of brick-red paste. Under a microscope this paste is seen to contain many orange-red crystals, but no recognizable blood corpuscles. In all major respects, including the presence of this unusual placental sac, the placentation of the sea otter resembles that of the river otter described by Bischoff (Sitzungsberichte der königl. bayer Akademie der Wissenschaften zu München, 1865, 1: 213–225).

The ovaries are compressed ovals completely hidden between fat-filled mesenteries. The left ovary weighs 1.44 grams, and contains only follicles smaller than 1 mm. in diameter. The right ovary (the side that contained the fetus) weighs 1.22 grams, and contains small follicles and a single corpus luteum that measures 5½ x 3 mm. in diameter. Neither follicles nor the corpus luteum project from the surface of the ovary. Unlike the ovaries of other mustelids that I have examined, both ovaries of our specimen are scored by irregular surface fissures as much as 3½ mm. deep and reminiscent of cerebral fissures. The tunica albuginea follows these clefts into the interior of the ovary and is not penetrated by them.

The fetus, a female, measured in millimeters: total length, 464; tail, 82; hind foot, 100; ear from notch, 12; ear from crown, 10; weight, 3.0 pounds. Since Fisher (Jour. Mamm., 1940, 21: 132–137) states that young are about 38 cm. long when born, and since mammary tissue in the inguinal region of our specimen had developed to about 20 mm. in thickness, I assume that the fetus was near birth. The eyes were open and the fur longer than that of the mother. After being prepared into a study skin, the fetus resembles a small fisher, but of course is short-tailed. The fur over the head and shoulders is Hair Brown (capitalized colors from Ridgway, 1886, Nomenclature of Colors) while over the rest of the body, except for the pale chin, it is darker (Clove Brown), not golden brown or straw-colored as has been reported for nursing young sea otters. The feet are black. The mother is a white-headed individual.—OLIVER P. PEARSON, *Museum of Vertebrate Zoology, University of California, Berkeley, California. Received August 11, 1951.*

THE DEVELOPMENT OF A YOUNG HARVEST MOUSE, *REITHRODONTOMYS*

While trapping mammals on the Tanglewood Biological Station of the University of Alabama in Hale County, Alabama, several specimens of *Reithrodontomys humulis humulis* were taken in live box traps. A gravid female was captured on July 16, 1951, and maintained in the laboratory for observation. On July 22, at approximately 10:00 A. M., she gave birth to two young. These were naked and unpigmented with the eyes closed and covered by a thin membrane. The ears resembled fleshy nubs with no internal openings apparent. One hour after birth the young measured 35 mm. in total length with a tail length of 10 mm. The young were observed suckling at 5:00 P. M. Cotton and grass were placed in the cage to provide a nest. The following morning these had been woven into a nest which resembled a loosely shredded hollow sphere. The mother and one young were noticed inside the nest while the other young was found dead in the cage.

When the surviving young was four days old, a well-defined band of black pigment had developed on the back, extending from the base of the tail to the center of the head. The tail was also pigmented except for a narrow line on the underside. The eyes were still closed, but a definite groove was appearing in the center of the membrane covering them. The young was soon able to squat in an upright position without falling, but there was no evidence of its being able to move about with any dexterity.

Five days after birth the first body hair was noticed in the head and neck region. The hair was silky and unpigmented with the whiskers fairly well developed. Pigment had appeared on the knees and the tips of the ears, with the dorsal pigmented band broadening slightly laterally. The young now measured 57.5 mm. in total length and 17.5 mm. in tail length.

Six days after birth, the back was sparsely covered with grayish hair with a tinge of brown hair at the base of the ears. The ear lobes were still hairless. The ventral surface was covered with a relatively thick supply of fine gray hair. This seemed to indicate that the hair was now growing predominantly in the ventral region rather than in the original dorsolateral pattern. The sex of the young was readily determined as female since the teats were rather well defined.

Eight days after birth, the hair on the dorsal side was considerably darker with the underparts having a grayish tinge. The point at which the dorsal pigmented band ceased to grow laterally seemed to be the line of demarcation between the darker upper parts and the lighter underparts. Fine gray hairs were noticed on the tail and a few white hairs were apparent on the feet. The activity of the young was decidedly increased since the last observation. The total length was now 67.5 mm. with the tail length 30 mm.

On the ninth day the ears had become darkly pigmented, but no hair was noticeable. The ears were still small and fleshy and seemed to mature rather slowly in comparison to the rest of the body. The ventral gray hair had thickened somewhat and the young began to resemble, in general coloration, the adult, though considerably darker above.

On the tenth day of observation the right eye was partially open. The browner hair around the base of the ears had become more prominent and extended slightly onto the face. The presence of teeth was detected when the young attempted to bite while being measured. The total length was 75 mm. and the tail length was 32 mm.

Inspection of the young on the eleventh day after birth found the animal climbing about the cage with great agility. Both eyes were completely open. The ears were well haired and had begun to take on a definite "ear" shape. No further measurements could be taken because of the activity of the young.

On subsequent observation no significant changes were noticed except a progressive increase in size. The juvenile was chloroformed and mounted after it reached the age of twenty-two days. The final measurements were: total length, 101 mm.; tail, 48 mm.; hind foot, 14 mm.; ear, 10 mm.—B. F. Holding and O. L. Royal, *Department of Biology, University of Alabama.* *Received September 6, 1951.*

ADDITIONAL NOTES ON THE GESTATION PERIOD OF THE WOODCHUCK

In the November, 1950, issue of the Journal of Mammalogy, my husband and I reported the gestation period in the case of a pet woodchuck, as it was determined in the spring of

1949. This period was 31 days and approximately 10 hours. Two additional matings of the same pair of animals have furnished similar data.

Pre-mating behavior was similar to that previously reported. In 1950, mating occurred several weeks earlier than in 1949, the date being March 4 as compared with March 29 the previous year. The first young was born early in the morning of April 5, 31 days and 22 hours after mating. Three more followed in the next two hours.

In 1951 they were kept separated a little later than the previous year, for unavoidable reasons, so the date of mating may not represent the earliest they would have mated under natural conditions. Copulation occurred on March 14, and the first young was born exactly 32 days later, on April 15.

From these three instances, which it must be remembered are under semi-laboratory conditions, it would seem that the gestation period for the woodchuck, *Marmota monax*, may safely be assumed to be approximately 31–32 days.—Sally F. Hoyt (*from the notes of* Southgate Y. Hoyt), *"Aviana," Etna, N. Y. Received August 20, 1951.*

A LATE BREEDING CYCLE IN *PEROMYSCUS*

The white-footed mouse, *Peromyscus leucopus*, is well known for its great fecundity and its occasional practice of breeding in winter. Several years' trapping efforts in the vicinity of East Lansing, Ingham County, Michigan, have disclosed a later-than-usual breeding cycle in the autumn of 1950. In connection with the NACSM autumn sampling, records from two trap lines in Baker Woodlot are available since 1948. In 1950, ten of the eleven adults captured from October 13–15 were breeding. Four of these were males, and in three the testes were scrotal in position. Of the seven females taken, five were lactating and the other two pregnant. One of the latter contained four and the other six embryos, all of which measured 4 to 5 mm. in length, C.R. This late breeding activity seemed noteworthy in view of the fact that, of seventeen adults taken at comparable times in 1948 and 1949, only four females were lactating, apparently the last of the breeders. The general nature of this late breeding in the fall of 1950 was reflected in a series of *Peromyscus* collected by my students the following winter, all near East Lansing. Of 78 specimens taken between January 14 and March 4, thirteen were immature, the smallest measuring 123 mm. in total length. One smaller individual, only 90 mm. long, was collected in nearby Kalamazoo County on March 3. My trap lines in Baker Woodlot, from May 15–17, 1951, netted a total of thirteen *Peromyscus*, where five or less had been the total during comparable periods in each of the three previous years.

The impression was general that the autumn of 1950 was a long and balmy one, with cold weather delayed beyond its usual date, permitting the mice to raise one extra litter before the onset of winter. An analysis of the official Weather Bureau figures, however, fails to indicate any great departure from the normal with respect to mean or extreme temperatures, dates of first frost, or precipitation. Nor does an analysis of figures of possible sunshine or of barometric pressure indicate any causal relationship with the breeding of *Peromyscus*. Unfortunately, no data are available on the relative abundance of food, or of predators, during this autumn or the following winter. These are probably only a few among many complex and variable factors, all of which may exert an influence on the rate of breeding and the survival of the resulting offspring.—Richard H. Manville, *Michigan State College, East Lansing. Received September 21, 1951.*

THE SURVIVAL OF BRAZILIAN MAMMALS

To the majority of foreign naturalists who still do not know Brazil, it may seem that this country is a great natural reservoir of wild mammals. Doubtless, they know that the Brazilian fauna is relatively poor, especially for the so-called big game, but the knowledge of its vast area, as well as of its scarce population, may generate the supposition that great numbers of wild animals live in the jungles of this portion of South America.

Unhappily, extermination of the mammals in Brazil goes on at a pace completely disproportionate to the progress of this vast country. There are still huge wildernesses in the Brazilian "far-west," but even there the wild mammals do not attain the abundance which characterized the mammalian fauna of East and South Africa or the North American Great

Plains. Considered generally, Brazil has a rural population scattered throughout its territory, which brings the human influence to practically all its corners. Since firearms, sometimes powerful, are largely used in Brazil by exceedingly primitive brains, the slaughter of wild mammals has no limit in this country. Being only a few species of large mammals, the pressure over each one of them is logically incalculable.

The heavy, long-tusked mastodons (*Dibelodon*) which roamed the Brazilian jungles in Pleistocene times became extinct long ago. With them disappeared the saber-toothed tigers, glyptodonts, *Megatherium*, and Pleistocene horses. The "anta" or tapir survived, becoming with its modest weight of less than six hundred pounds, the largest land mammal of South America. Like this shy mammal, there came from North America the only other notable immigrants of large mammals still living, the Cervidae of the genus *Odocoileus*, represented by two species. One of these had its southward way broken off by the equatorial forests and was restricted to the grassy plains of northern Amazonas state. The other, having attained the vast plains between northern Argentina and the Amazonian Basin, repeated the fate of the white rhinoceros of South Africa. Its range remained restricted, though appreciable numbers were attained. And, just as East Africa became depleted of white rhinos, the pampas and the eastern plains of Brazil did not know *Odocoileus paludosus*, the beautiful "cervo" (portuguese word, meaning hart or stag). Among the Carnivora, excells the famous "onça" or jaguar, whose size is much inferior to that of normal tigers and lions, but the Brazilian hunters kill it, generally, in the most cowardly way they can. One who knows the old methods used in British East Africa, for hunting lions, becomes shocked at the sight of several men armed with heavy guns and "zagaia" (a spear employed in the Brazilian "far-west") massacring an "onça" already attacked by dozens of dogs.

It would seem evident that, with so few large mammals, the problem of conserving them would be relatively easy in Brazil. But, though there are now game laws more or less adequate, the obedience to these is nearly nil; the people take advantage of the inefficient hunting control to slaughter the Brazilian fauna. Consequently, even in the most uncivilized regions of Brazil, the animal population decreases frightfully.

The first measure to be taken must consist of the organization of wildlife refuges, and the Brazilian Government has provided for that by means of the Hunting Code. Nevertheless, it is alleged that there is no money at all, from federal sources, to accomplish this task, and nothing is done. I am leading a campaign for the creation of the first refuges, but up to the present moment the conservationist movement remains embryonic in Brazil. All that this country possesses, for Nature's preservation, are three national parks, established in places formerly wasted for agricultural and other purposes, and where, of course, almost the whole primitive fauna was exterminated. In Brazil, there is not a special service to manage the wildlife within the national parks and, for this reason, the recuperation of its most remarkable mammals is something seemingly very distant. In one of the Brazilian national parks, a few tapirs survive, hidden within the summits of hostile mountains, and their extermination will soon be accomplished if no urgent measure be taken. The wild pigs or peccaries, the "onça," and the "capivara" (*Hydrochoerus*) have disappeared irredeemably from these areas. The "cervo," the so-called "pampas deer" (*Odocoileus campestris*), the "tamanduá-bandeira" (*Myrmecophaga jubata*), and the "guará" or maned-wolf (*Chrysocyon*) were never found inside any national park or wildlife refuge.

Certainly, it is a depressive situation, that of the Brazilian fauna. Although the country's Government recognizes its value and need of preservation, nearly nothing is done in this field, and everything relies upon the citizens conscience. And since the slaughter remains, it will be not an exaggerated pessimism to fear that soon the largest South American mammals may disappear forever.—Luiz Carlos de Mesquita Maia, *Rua Toneleros nº 210 casa 14, Copacabana, Rio de Janeiro, Brasil, South America.* *Received September 6, 1951.*

THE MYTH OF MONTEZUMA'S BISON AND THE TYPE LOCALITY OF THE SPECIES

In various general references on north American mammals, and on the bison, it is stated that the Aztec "emperor" had a bison in his zoological collection in Mexico City in 1519–

1521, and that this animal so impressed the conquistadores that Cortés had his historian-artist draw a sketch of it immediately. The story is given in many standard or general works (W. T. Hornaday, *Ann. Rep. U. S. Nat. Mus., 1887*, 367–548, 1889; E. T. Seton, LIVES OF GAME ANIMALS III: 644, 1929; Martin Garretson, THE AMERICAN BISON, N. Y. Zoöl. Soc., 1938; Victor Cahalane, MAMMALS OF NORTH AMERICA, 1947, p. 71; F. G. Roe, THE NORTH AMERICAN BUFFALO, 1951, p. 206). The only known early source for this story, quoted or cited by a few of these writers, is Antonio de Solís y Rivadeneyra, HISTORIA DE LA CONQUISTA DE MEXICO, completed in 1683 and first published in 1684 in Madrid. The versions of Solís to which the biologists refer are a French edition of 1691, cited by Seton, and an English translation by Thomas Townsend, published in London in 1724, of which there are copies at the University of Arizona library in Tucson and at the Laboratory of Anthropology in Santa Fe.

Contemporary accounts of the conquest of Mexico do not seem to mention the bison. In particular, Bernal Diaz del Castillo, who was there in person, describes Montezuma's zoo and mentions tigers, lions, and foxes, as well as rattlesnakes and a great variety of colorful birds; but he makes no reference to anything like a bison.

Solís was born in 1610 and spent his entire life in Spain. I suspect that, writing 160 years after the conquest, he invented the story of Montezuma's bison, incorporating a later description. Having never been in Mexico himself, Solís assumed there would have been one in a collection of the animals of the country. The story was not only picked up by later writers, but was given the added touch about the historian-artist. Solís does not make any statement that Cortés had it illustrated. A highly possible source of this idea is that Solís has been referred to as combining in his writings the aspects of historian and artist; apparently it has been assumed that he was a companion of Cortés.

The type locality of *Bison bison* is generally given as Mexico, not primarily because of the myth discussed above, but on the basis of the sixteenth-century description by Dr. Francisco Hernández, whom Linnaeus cites ("Taurus mexicanus, *Hern. mex.* 587. *Gesn. quadr.* 301. Habitat in Mexico, Florida." C. Linn. *Syst. Nat.* T. 1, Ed. dec., 1758, p. 72). Hernández very probably, I imagine, placed the bison in "New Spain," which included Mexico, but also included the western and southern United States. I have not yet located a copy of his great work on the natural history of the New World.

Francisco Javier Clavigero, S. J., devotes a chapter to the quadrupeds of the realm of Mexico in his HISTORIA ANTIGUA DE MEXICO, completed in 1784, first published in 1787 (the year of his death); but he does not mention the bison, although he draws largely on Dr. Hernández.

In the other great early work of this kind, HISTORIA GENERAL Y NATURAL DE LAS INDIAS (1535), Gonzalo Fernández de Oviedo y Valdes states, in Lib. XII, Cap. XL ("De las vacas de la tierra septentrional"), that, according to those who have been in the northern part of the mainland, "á las espaldas de la provinçia que llaman la Florida," there are many wild cattle in that region. The brief description of those "vacas y toros monteses" is repeated farther on in connection with Ponce de Leon's expedition to Florida in 1513. Oviedo's would seem to be the first published description of the American bison, although his illustration looks more like a gnu!

A fairly good description of the bison was given in 1554 in the HISTORIA GENERAL DE LA INDIAS of Francisco López de Gómara, together with a passable illustration (reproduced as Plate LV in G. P. Winship, "The Coronado Expedition, 1540–42," 14th Ann. Rep. Bur. Amer. Ethnol., 1892–93, 1896).

The first reference to bison in the west is that of Alvar Nuñez Cabeza de Vaca, who evidently saw them in eastern or central Texas between 1528 and 1533, before the long walk to Mexico in 1535, during which none were encountered. In 1539 Fray Marcos de Niza, coming up the west coast of Mexico to Arizona, heard of the bison, but saw none. The first Europeans to see the great herd on the plains were undoubtedly the Spaniards and others of the expedition of Franciso Vásquez de Coronado, in eastern New Mexico and the panhandle of Texas in early May, 1541.

There seems to be no positive documentary evidence for the presence of bison in north-

eastern Mexico within the historic period. The bison did not, apparently, range west or south of the Rio Grande in the sixteenth century; bison remains found archaeologically west of the Rio Grande, in western New Mexico and Arizona, date from the 1200's or before. At a far earlier time, various species are known to have extended much farther west and south; evidently the range of the bison contracted steadily from the terminal Pleistocene times onward.

To the south the bison is often said to have extended across northern Coahuila into Chihuahua, but I can find little historical basis for this statement. In Trans-Pecos Texas the bison ranged across the lower Pecos River country as far as the vicinity of Comanche Springs (Fort Stockton), but is not recorded for the Big Bend proper. The Bosque-Larios expedition of 1675 to western Texas met bison only some distance north of the Rio Grande; and in 1683 Mendoza found them in west Texas only around Fort Stockton and eastward (H. E. Bolton, SPANISH EXPLORATION IN THE SOUTHWEST, 1542–1706, New York, 1916, pp. 298, 328). Bison remains found archaeologically in a late-prehistoric and early-historic archaeological site at La Junta (Presidio, Texas) by Dr. J. Charles Kelley could easily have been brought from the plains.

The statement from the Berlandier manuscript quoted by Hornaday on buffalo in Chihuahua, Durango, and Nuevo León in the seventeenth century seems to stand almost alone and unsupported. Until I find a positive contemporary reference, I shall be very dubious as to early-historic (1500–1700) bison beyond the Rio Grande.

The closest to such documentation is the statement by Obregón that in the 1565 expedition to "Paquimé" with Ibarra they saw hides, bones, and manure of "the cattle;" but the local people, *querechos*, told them that the cattle were four days' march away and that they themselves were enemies of those *querechos* who "lived among the cattle;" also that the cattle came up into the slopes and sheltered places to get away from the cold in the open country (G. P. Hammond and A. Ray, OBREGÓN'S HISTORY, Los Angeles, 1928, pp. 202–203, 215). This all sounds rather peculiar and slightly confused, and I am not sure that the traces they saw were really of bison. "Paquimé" is thought to have been the Casas Grandes vicinity in Chihuahua.

Another relevant contemporary source is an eighteenth-century account of Sonora by the Jesuit friar Pfefferkorn, which describes bison in the region to the northeast—"In den Wildnissen, welche gegen Nordösten in die Gebirge der Apaches beruhen"—a rather general term which could in fact refer to eastern New Mexico and West Texas; he evidently based this on information from others (Ignaz Pfefferkorn, BESCHREIBUNG DER LANDSCHAFT SONORA, Köln, 1794, I: 234; Theodore E. Treutlein, transl. and ed., PFEFFERKORN'S DESCRIPTION OF THE PROVINCE OF SONORA, Univ. New Mex., Albuquerque, 1949, p. 102).

The type locality for *Bison bison* should, it appears, actually be given as the southern or southeastern United States, not Mexico. Probably no bison at all remained in what is now known as Mexico by the sixteenth century.—ERIK K. REED, *Santa Fe, New Mexico. Received September 11, 1951.*

METHOD FOR KEEPING THE EASTERN MOLE IN CAPTIVITY

Various investigators, Hanawalt (M. S. Thesis, Ohio State University, 1921), Howell (Jour. Mamm., 4: 253, 1923), Arlton (Jour. Mamm., 17: 349–71, 1936), and Bennett *et al.* (Ann. Rept. Agric. and Hort. Res. Sta., Bristol, England, pp. 51–55, 1942), have attempted to keep moles in captivity for extended periods of time, and such efforts have sometimes involved considerable difficulty or complete failure. In tests described by Hisaw (Jour. Mamm., 4: 9–20, 1923) moles were kept in captivity for several months (one mole for over a year) on artificial foods that were supplemented by natural foods such as earthworms and various insects. Owing to the desire for testing many poisons on captive moles a method was developed for keeping them in captivity for an extended period of time on artificial foods. One eastern mole (*Scalopus aquaticus*) was kept in an apparently healthy condition for over 14 months, and a Brewer's mole (*Parascalops*) was kept by the same method for five weeks.

On a heavily infested golf course 14 moles were captured by hand, and 33 by use of live mole traps slightly modified from the one described by Moore (Jour. Mamm., 21: 223–25, 1940). The live traps used in this work had a strip of sheet metal, instead of a board, to support the spikes, and guides at each end provided increased rigidity for the spike-support when the trap was sprung.

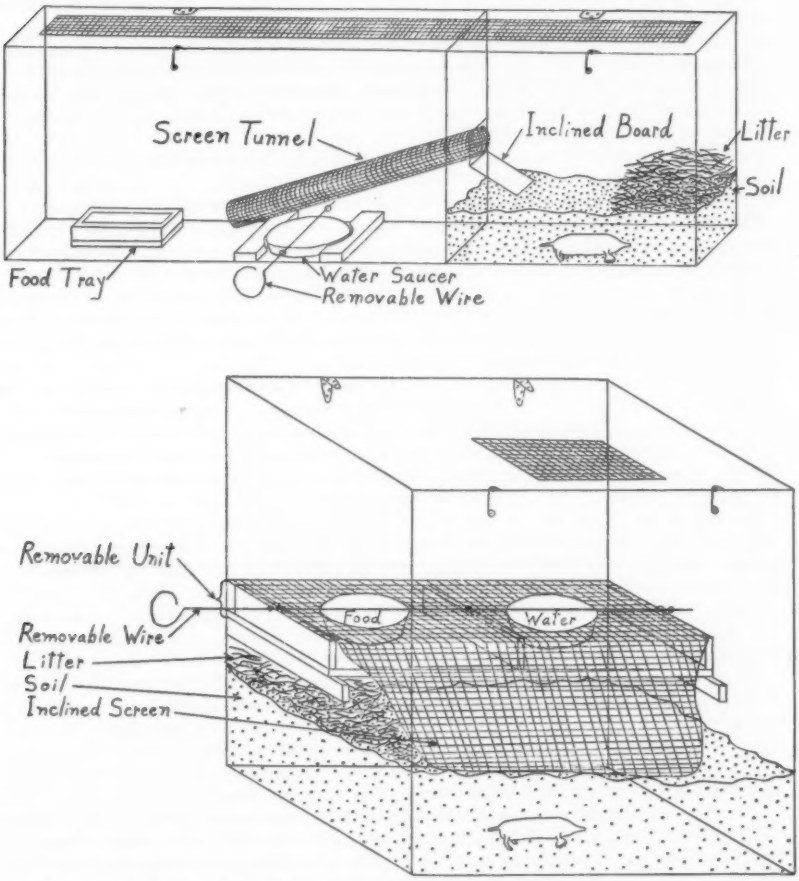

FIG. 1.—Diagram of type of cage first designed (upper) and of modified type that can be cleaned easily (lower).

Each live trap was examined once or twice daily. Ordinarily each trap was removed to a new location at the end of 24 hours, regardless of whether specimens were caught or not. During supposed periods of rutting two moles were trapped from the same site, in two instances. Of those obtained by use of live traps only one was found dead in the trap.

The two types of cages used are shown in Figure 1. In cage no. 1 (Fig. 1, upper) the soil level was slightly below the level of the opening of the tunnel. In cage no. 2, (Fig. 1, lower)

the screen of the lid was on the side opposite the food and water containers. The latter type of cage has the following advantages: (1) more easily cleaned; (2) easier to keep dirt away from the food and water containers; (3) less space required for cage; and (4) greater ease of handling. Cage no. 1 seemed to provide more suitable conditions for newly captured moles.

Moles recently taken into captivity nearly always responded to artificial foods during the first night, if allowed to remain in a tall glass container having an excess of dry litter, and ground meat on the bottom. If the food was not eaten, some pieces of earthworms or mangled insects mixed with fresh ground meat were used. May beetles and white grubs were readily accepted. All the moles kept thus far and given the proper care accepted raw ground beef or a dog food having ground horse meat, whole wheat, ground bone, brewer's yeast, and a few other ingredients. Meat that was not ground or cut into small pieces was masticated with considerable difficulty.

Moles that were fed only dog food showed symptoms of dietary deficiencies after a month or more. The addition of a pinch or two of a mixture of vitamins A, B complex, C, and D apparently helped to supply the deficiencies. However, there was evidence that the dog food and vitamin mixture was not completely fortified for all the individuals until a pinch or two of chopped grass blades, and 1.5 to 2.0 cubic centimeters of raw beef or pork liver were added. The amount fed per day for an average feeding by weight was from 25 to 30 grams of the dog food, 0.3 gram of grass clippings, 0.6 gram of the vitamin mixture, and 0.7 gram of liver. When raw ground meat was used it was fed twice per day. The food and water containers were cleaned thoroughly each day. Cleaning of the food container was reduced to a minimum by lining it with oil paper and newspaper.

Disease, parasites and/or vitamin deficiencies probably contributed to death in nine of the first ten moles kept in captivity. Symptoms varied among the nine moles which were thought to have vitamin deficiencies. Among these were loss of hair, loss of appetite, and scaliness of skin. Two moles, one of which also indicated vitamin deficiencies, were heavily infested with mites. The loss of hair of some specimens might have been due to mange mites, although this was never investigated.

In case of flea infestation, the moles were dusted, without apparent injury, with 10 per cent DDT dust. Mites were the most common parasites and were treated with 12 per cent gamma Benzene Hexachloride wettable powder. Another miticide that was found to give satisfactory results consisted of 50 per cent p-chlorophenyl-p-chlorobenzene-sulphonate wettable powder. Following a treatment with any of the above materials the individual was always allowed to burrow through soil an hour or more in order to prevent excess contamination of the cages.

One individual which was captured by hand died, presumably of starvation, within two or three hours of the time it was taken. An autopsy revealed the presence of two nematode worms in its stomach and three acanthocephalid worms in its small intestine.

An abundant supply of fresh dry litter was kept in the soil compartment. Ground corn cob or similar material was added to open parts of the cage in order to reduce offensive odors, and the entire cage was cleaned thoroughly once each month.

The cages with the captive moles were kept in a basement room during all four seasons of the year. It seems probable that the temperature of the room was relatively constant, particularly during the cooler weather. During the latter season a fan that was in the hallway leading to the room was controlled by a thermostat which was usually set at 76°F.

The effectiveness of the method is illustrated by mole no. 10, which was kept in captivity for over 14½ months before being used in a test of a poison bait. Two specimens were kept 6 months and 21 days. One of these was killed by poison and the other one died, presumably from vitamin deficiencies. A fourth specimen was kept for 5 months and 10 days before being killed by a poison in a test. The maximum possible length of time a mole may be kept healthy in captivity by this method was not determined.

In all, 24 moles were kept in cages during the course of this study. Five were caught while trapping with regular harpoon traps and remained alive in the cages from two to eight days in spite of the injury from the spikes.

Moles were usually picked up by grasping the skin of the back. They were held by the tail or by a hind leg while being examined. Defense was usually by use of the fore feet although the animal commonly responded by biting when aggravated.

Two moles of the same or of different sexes were kept in the same cage. It was found best to partition one of the type 1 cages if the moles were to be kept together for any length of time. One mole escaped a cage and was recovered between two and three days later, in normal health. Breeding of moles in captivity seems to be very improbable on the basis of observations made during this work.—WILLARD LOREN HENNING, *Biol. Dept., Arkansas College, Batesville, Arkansas.* *Received September 29, 1951.*

A PROGRAM FOR MAINTAINING THE FREETAIL BAT IN CAPTIVITY

The Mexican freetail bat, *Tadarida mexicana* (Saussure), is generally considered unadaptable to life in captivity. It is known to refuse food persistently, and patiently starve to death. Perry (Nat. Hist., 56: 178–83, 1947) was the first to record a successful attempt to adapt this species to captive life. A single bat was trained to eat mealworm larvae of the grain beetle (*Tenebrio molitor*), water boatmen, cottage cheese, and "Pablum" cereal moistened with water or evaporated milk.

Numerous earlier attempts on the part of the writer, dating from 1938 to 1944, met with defeat. Since that period, however, it has been found possible on four occasions to maintain in captivity varying numbers of bats of this species. The first three successful attempts are reviewed here in the order of their occurrence, with discussion of points of especial interest. The fourth and latest program will be described in greater detail.

Early programs.—During the summer of 1944, a freetail bat was introduced to a thriving captive colony of *Antrozous pallidus pallidus* at Los Angeles, California. The bats were confined in a 2 x 4 x 4-foot screen-covered wooden frame cage with wooden floor and back. A light bulb housed in a metal box and secured against the back wall provided a source of heat. The cage was kept in an open shed, exposed to outside temperatures and humidity, but protected from extreme drafts. The bats regulated their immediate environmental temperatures by hanging on the wall near the light on cool evenings and at a greater distance on warm evenings. Under this regime, the freetail bat readily accepted mealworms offered on forceps. Water was lapped from a petri dish on the floor of the cage. The freetail bat was released after three weeks of captivity.

In the summer of 1949, two bats of this species were successfully maintained at Los Angeles City College for a period of 34 days, after which period they were released. They were housed in an ill-ventilated 2 x 2 x 4-foot glass chamber at 78–84°F. and 71–81 per cent relative humidity. They avidly consumed mealworms which were delivered on forceps. Water was available in a petri dish on the floor of the cage.

In November, 1949, seventeen *Tadarida mexicana*, collected at Davis, California, were placed in a 1 x 1 x 2-foot wire-covered wooden frame cage with wooden floor and door. The cage was kept in a warm room on the campus of the University of California at Davis. The temperature range of this room varied between 78–84°F., and the relative humidity varied between 50–70 per cent. The bats soon learned to accept mealworms and housefly pupae when offered on forceps. Before very long, several industrious individuals discovered the temporary food reservoir in a petri dish placed on the floor of the cage during feeding time, and proceeded to help themselves. Seven individual bats acquired this habit, and the practice resulted in seven fat bats and rapidly diminishing food stores. After 52 days this program was abandoned due to a lack of sufficient quantities of food.

Factors leading to success of early programs.—A review of the conditions under which resting *Tadarida* have accepted food in captivity would seem to indicate that the chief reason for this success was the fact that the bats were maintained at high temperatures and rather high relative humidity, under which conditions relatively little heat loss was suffered.

That resting bats assume the temperature of their immediate environment was first demonstrated by Hall (Philos. Trans. Royal Soc. London, 1832). Hock (Thesis, Cornell Univ., 1949) produced conclusive evidence that the metabolism of resting bats is directly proportional to the temperature of the immediate environment. Thus, when a bat comes to

rest in a low environmental temperature it quickly assumes a temperature near that of the environment and enters a state of torpidity, the depth of which increases as the temperature is lowered.

The writer's earliest attempts to feed captive *Tadarida* were made with isolated resting bats, maintained in wire cages at room temperature. It is easy to visualize why the attempts failed—the bats were semi-dormant or for all practical purposes asleep.

An outstanding natural example of the effect of the environmental conditions in producing a lowering of the body temperature of resting *Tadarida* was afforded by an examination of a colony of this species on February 23, 1947, at Kane Springs, Imperial County, California. The air temperature was 80°F. and the relative humidity was 21 per cent. Several bats, dislodged from their roosting quarters between the beams of a bridge, felt cold, and could move only very slowly. Such a situation is not of frequent occurrence, however, for bats of this species usually select a daytime retreat the temperature of which is above that of the outside temperature. The retreat may be in a small hole or crack in which the bat suffers little heat loss, its immediate environmental temperature being raised to near that of its body by retention of body heat. More open roosting places, such as attics, are quite warm due to the heating effect of the sun and poor ventilation. If no such favorable condition exists, the bats hang in a mass several bat layers deep and thus conserve heat. The bats at Kane Springs had attempted to take the latter precaution, but a strong steady wind had apparently reduced their body temperatures through convection and evaporation.

As a result of the foregoing considerations, it was concluded that captive *Tadarida* should be maintained at a high environmental temperature with high relative humidity. The high temperature keeps the bats active; the humidity aids this effect by reducing loss of heat by evaporation.

Detailed account of a recent program.—On May 24, 1951, forty-eight Mexican freetail bats, collected several days earlier in Arizona by Mr. Loran Whitelock, arrived at the United States Public Health Service Arctic Health Research Center at Anchorage, Alaska, for use in experiments. It was necessary to establish a care program with the following characteristics: 1) the use of mealworms as food, 2) isolation of each individual, 3) a source of water presenting a water surface area of sufficient size so that it could be easily located, but not of such a nature that the bats would get wet or drown, 4) arrangements so that the bats could hang head-downward, 5) a provision whereby bats could be removed from quarters without actually touching them, and 6) reduction of maintenance time to a minimum.

As the bats were removed from the shipping cage, they were weighed and marked for later recognition. The marking consisted of attaching aluminum bird bands of No. 0 size to the right forearm. They were immediately transferred to an environment designed to prepare them for a course in mealworm feeding; this was a small warm room maintained at a temperature of 86°F. and 62 per cent relative humidity.

Each bat was housed separately in a pint-size ice cream carton with screen lid. This carton served as sleeping and eating quarters. During the sleeping period a cylinder of plastic window screen, the length of the carton and slightly smaller in circumference, was placed inside the carton in order that the bat would have vertical footholds for assuming a head-downward position. During the feeding period the cylinder was removed to encourage the bat to remain on the floor of the carton and thus be in immediate contact with the mealworms which were placed there at the beginning of that period.

Water was available in a wide-mouthed bottle, 1½ inches high and 3½ inches in circumference. The weight of the jar prevented the bat from overturning it, and its sides were high enough so that the bat could not stumble into it. The water surface area was such that it was readily located; the bottle opening was wide enough for the bat to insert its head and neck, but not its forelimbs, thus eliminating danger of drowning.

The bat could easily be moved from its quarters without being touched by merely lifting out the plastic cylinder to which it would cling. This was done when the cartons were to be cleaned or when transferring the bat to experimental apparatus.

Training to accept mealworms.—Training the bats to eat mealworms was by far the most taxing aspect of the program. This job was undertaken immediately after the bats arrived. Initial measures necessitate treating each bat individually with the expenditure of much time. This segment of the program is divisible into a number of steps designed to encourage the bat to accept a mealworm diet. Ten mealworms were placed on the floor of each ice cream container in the hope that the bat would recognize its future diet. However, this was not expected to take effect at once and it was first necessary to hold the bat in hand and place a decapitated mealworm, neck first, in its mouth. This prompted the bat to close its jaws, and if it did not begin to chew within one-half minute a drop of water was expelled from a medicine dropper into the corner of its mouth. If this failed to produce the desired results the contents of the mealworm were squeezed out of the skin through the neck opening into the bat's mouth. As a last measure, and one originating from the worker's state of extreme exasperation, the nose of the bat was grasped with forceps and pinched. This either prompted the bat to recognize its position, enraged it, or stimulated memories of counteroffensive actions of captured prey, for the bat usually consumed the worm in a very determined manner.

After the first mealworm was eaten the bat was placed on the floor of its quarters and a mealworm was delivered on forceps to the muzzle of the bat. If the worm was refused the bat was again taken in hand, and the process was repeated. If it was accepted the bat was left in its quarters for one-half hour, that it might have sufficient time to demonstrate its ability to recognize and feed upon the remaining mealworms on the floor of the carton. If results were negative, the remaining worms were delivered to the bat's muzzle until ten had been consumed or the bat no longer accepted them.

To work in this manner with the entire group required 24 hours the first day; the bats accepted an average of 2.14 mealworms each. When the last bat had been fed the procedure was repeated at once and again required 24 hours; the bats accepted an average of 5.6 mealworms each. After four hours the process was again repeated, requiring 18 hours. The food consumption rose to 9.1 mealworms per bat. After six hours the bats were again fed. This period lasted 16 hours and each bat was ready to accept a minimum of 10 mealworms. By this time nine of the bats had learned to feed themselves.

In the time that followed, bats were periodically sacrificed in experiments and it was impossible to measure progress in terms of exact percentages of the original number which learned to feed themselves. Eighteen individuals established this habit, but many others were sacrificed before they had been given an adequate chance to do so.

By the end of the third feeding it was no longer necessary to encourage the bats to feed. All readily accepted mealworms when offered to them, or fed themselves. They preferred to eat the forcep-delivered worms head-first. By this time it was possible to feed nine bats at the same time.

After the bats had been confined for a period of 27 days, food and water was withheld for a period of 24 hours and the bats were weighed. They had gained an average of 0.5 gram each since their arrival.

Recommended modifications of the program.—This program meets the qualifications set forth earlier. Because experimental results were not dependent upon the physiological state of the bats, no provision was made to ensure an adequately balanced diet or to provide a means of exercise such as allowing the bats to fly. Obviously, if a normal colony is to be maintained, these factors and others should be considered. The food ration would, of course, need to be much larger and more varied. To reduce feeding time to a minimum, it would be advisable to start out with a larger group than is needed, discarding those individuals that fail to learn to feed themselves within a period of one week. Such individuals apparently never grasp the idea. Aged individuals are undesirable captives in the sense that they consume great amounts of time chewing their food, due to greatly worn teeth. It is suggested therefore, that if a large group is to be maintained a weeding-out process be undertaken.—DENNY G. CONSTANTINE, *Arctic Health Research Center, U. S. Public Health Service, Anchorage, Alaska.* *Received September 24, 1951.*

PIGMY SHREW, *MICROSOREX*, IN MONTANA

Among a group of small mammals sent to the U. S. National Museum for identification by Dr. William L. Jellison, of the U. S. Public Health Service, Hamilton, Montana, is a specimen of the pigmy shrew, *Microsorex hoyi washingtoni*. This alcoholic specimen, U.S.N.M. No. 291188, was obtained July 25, 1949, on the south fork of the Flathead River, about 20 miles south of Hungry Horse Dam, Flathead County, Montana. The circumstance of capture was similar to that described by Koford (Jour. Mamm. 19: 372).

This record constitutes the third known occurrence of the subspecies and the second for the State of Montana. The other localities are: Loon Lake, Stevens County, Washington, (type locality); and 7 miles east of Thompson Falls, Sanders County, Montana.—HENRY W. SETZER, *U. S. National Museum. Received October 10, 1951.*

ADDITIONAL RECORDS FOR WATER SHREWS, *SOREX PALUSTRIS*, IN NEW ENGLAND

The scarcity of information concerning *Sorex palustris* warrants the publishing of the following records for New England: On August 10, 1951, at Sharon Mt., Sharon, Litchfield County, Connecticut, a male was collected along a small stream, elevation, 700 feet, by the junior author. On August 11, 1951, another male was taken at the same locality, on the edge of a swamp, 1200 feet. On September 6, 1951, a male was taken along a stream in Low-Burbank Grant, Coos County, New Hampshire, elevation, 2700 feet.

The latter two specimens were collected by the senior authors. All three are probably referable to *S. p. albibarbis*. Study skins, skulls, and skeletons of these specimens are on deposit in the Vertebrate Zoology Collection at the University of Connecticut.—A. STARRETT, P. STARRETT, AND P. M. YOUNGMAN, *Dept. of Zoology and Entomology, Univ. of Conn., Storrs, Conn. Received October 17, 1951.*

PEROMYSCUS LEUCOPUS ON PEAK OF MT. WASHINGTON, COOS COUNTY, NEW HAMPSHIRE

One night's trapping on Mt. Washington in Coos County, New Hampshire, turned up two unusual records for *Peromyscus leucopus noveboracensis*. On September 5, 1951, an adult female was taken in a Sherman metal live-trap at 6200 feet, among the rocks and grassy vegetation of the summit. This specimen has been added to the authors' live colony, to be used in anticipated breeding experiments. Another adult female, total length, 172 mm.; tail, 81; hind foot, 20; and ear from notch, 16, was taken at 5000 feet, along with a young adult male and an immature male *Peromyscus maniculatus gracilis*, in a grass-sphagnum-stunted spruce habitat.

Osgood (Jour. Mamm., 19: 439, 1938) and others have found *P. leucopus*, in northern New England, to be limited to the lower altitudes, being replaced by *P. maniculatus* at higher elevations. Although there is no reason to believe that *P. maniculatus gracilis* is not found on the summit of Mt. Washington, it seemed to be noteworthy to find *P. leucopus noveboracensis* at these altitudes, at least 1000 feet above tree limit.

Study skins and skulls of the latter three specimens are on deposit in the Vertebrate Zoology Collection at the University of Connecticut.—A. STARRETT AND P. STARRETT, *Dept. Zool. and Ent., U. of Conn., Storrs, Conn. Received October 17, 1951.*

PRAIRIE VOLE, *MICROTUS OCHROGASTER*, IN EASTERN KENTUCKY

Welter and Sollberger (Jour. Mamm., 20: 77–81, 1939) recorded *Microtus pennsylvanicus pennsylvanicus* Ord from Rowan County, Kentucky, but apparently overlooked the existence of *Microtus ochrogaster* in the area.

I have recently examined 40 specimens of *Microtus* from the collections of Morehead State College, Morehead, Kentucky, taken at Morehead in 1938 and 1939. Thirty of the specimens are *pennsylvanicus;* ten, on the basis of dental characters, are obviously *ochrogaster*. Two of the specimens of *ochrogaster* exhibit a slightly buffy belly, but the re-

maining eight are externally similar to *pennsylvanicus*. In view of the close external resemblance of the specimens to *pennsylvanicus*, they are considered to be *Microtus ochrogaster ohionensis* Bole and Moulthrop.—ROGER W. BARBOUR, *Department of Zoology, University of Kentucky, Lexington, Kentucky. Received September 27, 1951.*

NEW PHENACOMYS RECORDS FROM COLORADO

One of the rarer small mammals occurring in the Rocky Mountain states is *Phenacomys intermedius intermedius* Merriam, which A. B. Howell in "Voles of the Genus Phenacomys" (N. Amer. Fauna, No. 48) called the Rocky Mountain Phenacomys for want of a better colloquial name. Since there have been fewer than a dozen records of this vole from Colorado up to this time the purpose of this note is to report six specimens recently taken by the author in Moon Gulch, Gilpin County, Colorado, approximately 2½ miles from Rollinsville, Colorado. These six animals were obtained along with numbers of *Sorex*, *Peromyscus*, *Microtus*, *Clethrionomys*, and *Zapus* in 2169 trap-nights set in a variety of habitats in the Gulch.

On July 9, 1951, a young male was taken in a Museum Special trap baited with a mixture of suet, peanut butter, raisins, and Roman meal, and set at the foot of a tree in a lodgepole pine forest at an altitude of approximately 8750 feet. On July 11 two traps, baited in similar fashion and set 50 feet apart in a moist stream bottom situation at about the same altitude, captured an immature male and a young female. The next night a trap placed near a fallen log 250 feet upstream from the latter spot caught a mature female carrying five embryos nearly at term. On July 20 a mature pregnant female was captured in a trap set on a steep grassy slope in a ponderosa pine community at a slightly higher elevation. Finally on August 2, 1951, another pregnant female was taken in a trap placed at the foot of a dead lodgepole pine in an area near the summit of Mt. Jumbo at the upper end of Moon Gulch, at an altitude of about 9800 feet. The trapping site was swept by a severe fire in 1938, but in the secondary succession that has established itself since then the ground is covered, somewhat sparsely in places, with a growth of grasses, forbs, shrubs, and the seedlings of lodgepole pine and Englemann spruce.

The variety of habitats in which these animals were taken is interesting in view of the fact that the vole is said to occur mainly in open grassy areas in the Canadian and Hudsonian zones, although F. W. Miller and R. L. Landberg of the Colorado Museum of Natural History, Denver, reported in 1931 the capture of a specimen in a trap set at the foot of a spruce on the bank of a stream near Alma, Park County, Colorado. It is hoped that further systematic trapping will reveal more concerning the distribution of this microtine in the state.—OLWEN WILLIAMS, *Department of Biology and University of Colorado Museum, University of Colorado, Boulder, Colorado. Received August 17, 1951.*

CHECKLIST OF PALAEARCTIC AND INDIAN MAMMALS—NEW NAME

On page 288 of the above work (also recorded on page 742) we noted that *Paradoxurus hermaphroditus fuscus* Miller, 1913, was preoccupied by *P. fuscus* Kelaart, 1852. We renamed the former *P. h. milleri*.

Mr. L. R. Conisbee has drawn our attention to the fact that our new name is itself preoccupied, by *Paradoxurus milleri* Kloss, 1908. We, therefore, propose *Paradoxurus hermaphroditus conisbeei* as a new name for *P. h. fuscus* Miller, 1913.—J. R. ELLERMAN AND T. C. S. MORRISON-SCOTT, *British Museum (Natural History), London, S.W. 7. Received April 1, 1952.*

REVIEWS

Ashbrook, Frank G. RAISING SMALL ANIMALS FOR PLEASURE AND PROFIT. New York, Toronto, and London: D. Van Nostrand Company. 8vo., pp. viii + 260, text figs. 152, mostly half-tones. November, 1951. Cloth, $4.00.

"Of the making of books there is no end!" And in keeping with such dictum many authors write many manuscripts on many subjects, then search for a publisher with more or less, or no success. Here, however, is a volume on a subject so needed, so often requested from book-dealers, that public demand induced the Van Nostrand Company to seek a qualified person to write the book for them. That is how it came that Frank G. Ashbrook wrote RAISING SMALL ANIMALS FOR PLEASURE AND PROFIT. The book is written in an easy entertaining style that is ideal reading for anyone interested in raising animals. Even though the reader might not have had the urge to raise animals, he would soon have such an urge stimulated as page after page of practical information and instructions were absorbed.

The book is divided into 15 chapters, the first three of which (1) Profitable side lines, (2) Practical side lines, and (3) Hints to beginners, are short, and might well have been combined in one chapter. Chapter 4 has to do with "Small animal projects," and includes such subjects as raising rabbits, guinea pigs, white mice and rats, hamsters, milk goats, and a discussion of sanitary pens. Chapter 5 deals with poultry raising and chapter 6 with game birds. Fur animals, devoted mainly to minks and chinchillas, is covered in chapter 7. These first seven chapters include about two-thirds of the book, then following are seven chapters devoted to such miscellanea as prevention and treatment of disease, record keeping, fish production, fish bait culture, other side lines worth considering, marketing and storing the produce, and recipes for unusual meats and fish.

In chapter 15 under the heading "Helpful References" we find seven appendixes conveniently arranged so as to afford excellent reference material for the details of methods and means not fully covered in the text. This constitutes a most useful part of the book, since with a subject of such huge coverage it would be impossible to go into technique minutia under each item discussed. The well selected references are arranged under Appendix A, Publications of the United States; Appendix B, United States Agricultural Experiment Stations; Appendix C, Reference Books; Appendix D, Periodicals; Appendix E, Breeders Associations; Appendix F, State Departments of Conservation and Game and Fish Commissions; and Appendix G, Purchasers of Small Animals.—HARTLEY H. T. JACKSON.

Martin, Alexander C., H. S. Zim, and A. L. Nelson. AMERICAN WILDLIFE AND PLANTS. New York: McGraw-Hill Book Company. Pp. ix + 500, numerous unnumbered figs. and maps. Price $7.50.

This book is planned "not only for wildlife technicians, sportsmen, naturalists, bird students, and all others directly interested in wildlife, but also for foresters, landscape gardeners, botanists, and additional groups concerned with the vegetation upon which our country's wildlife depend." To attempt to please and satisfy such a diverse group is a large order and one virtually impossible to achieve unless it be immediately understood that the book is intended as a helpful compendium, not as a definitive, exhaustive treatise on plant foods of American wildlife. With a knowledge of the true scope and purpose of the book in mind, zoologist, botanist, sportsman, and gardener, alike, will tend to overlook omissions and inconsistencies and will appreciate the large body of useful information skillfully brought together in the book.

Briefly put, this report consists of synopses of ranges and habits of many kinds of birds and mammals and of the foods, principally plants, consumed by those animals in the United States. The sources of the information are the extensive files of the U. S. Fish and Wildlife Service, supplemented to some extent, but not as fully as might be desired, by published reports from other sources.

There are three parts. Part I introduces the reader to some of the ways that plants are useful to animals, posts him on techniques of food-habits studies as practiced by Fish and Wildlife Service personnel, and describes for him the abbreviations and other symbols

employed in the body of the book. Synopses of the food, habits, and ranges of vertebrate animals comprise Part II. The treatment is highly selective as regards species. Birds receive the lion's share of attention; 171 pages are devoted to them. Accounts of mammals utilize 60 pages. The discussion of foods of reptiles, amphibians, and fish occupies 6 pages. Regarding criteria employed in selecting the wildlife species to be treated in the book, the authors state that "Groups that make little or no use of plants for food receive only brief comment. So do those which are rare or have a limited range. Species which use more plant food are treated in greater detail, especially if they are of economic or recreational importance." The birds and mammals are grouped into units, each comprising a chapter: waterbirds, marshbirds and shorebirds, upland gamebirds, songbirds, birds of prey, fur and game mammals, small mammals, and hoofed browsers. Within each chapter the genera are arranged according to standard check-lists. The units of birds are, coincidentally, largely natural units. Those of mammals, however, are highly artificial. For the convenience of the reader alone, if for no other reason, the authors might better have deleted the three categories for mammals and listed all of them according to a standard check-list arrangement. A typical account of a species of mammal contains: a map showing geographic range in the United States, a few statements regarding feeding habits, a graph indicating percentage of plant and animal food consumed in each season of the year, and a list of several plants arranged in order of importance as food to the species of mammal, as indicated by analyses of stomach contents and droppings. In Part III, which consists of 198 pages, 290 genera of plants that are important sources of food for birds and mammals are treated. For each genus there is given: a map showing geographic range, a brief account of habitat, an index of use by wildlife, and a list of wildlife species that eat the plant or parts of it in one or more of five regions of the U. S. In the last chapter of the book the plants are ranked by region and according to incidence of use as food by wildlife.

A few other notes, made as I read the book, follow. The numerous pen and ink sketches are, on the whole, pleasing and instructive. The figure on page 253 under the heading "Western Chipmunk," however, appears to be that of a golden-mantled groundsquirrel. The distribution maps indicate general, not precise, limits of ranges of the species. A species may or may not occur throughout the area indicated on the range map, or, on the other hand, the indicated range may exclude known occurrences. For example, the maps exclude *Dipodomys ordi* from northeastern Montana and *Oreamnos* from the Black Hills, South Dakota. *D. ordi* ranges across Montana into Canada. The mountain goat is as well established in the Black Hills as the opossum is at home in California (p. 219). For many vernacular names of plants the authors combine the constituent words into one, following the second edition of Standardized Plant Names by Kelsey and Dayton. While one may be somewhat startled when he first encounters the usages Douglasfir, Russianthistle, and giantcactus, he may soon drop his initial antipathy. I approve of the procedure of compounding one word from several as long as the meaning of each constituent word remains clear. Mammalogists also might well follow this procedure.

This is a reference volume, crammed with useful information. It is a valuable aid. The serious student who wishes to know for a particular wildlife species its food habits and specific foods throughout the year and throughout its geographic range, however, will still have to comb the literature and, likely, finally will have to take to the field himself.—EMMET T. HOOPER. *Museum of Zoology, University of Michigan, Ann Arbor.*

Ellerman, J. R., and T. C. S. Morrison-Scott. CHECKLIST OF PALAEARCTIC AND INDIAN MAMMALS 1758 TO 1946. London. British Museum (Natural History), 810 pp., 1 map, 19 November 1951. Price, 3 pounds 5 shillings.

Mammalogists in particular, and zoologists in general, should welcome the appearance of this valuable reference work. With Allen's Checklist of African Mammals, Chasen's Handlist of Malaysian Mammals, and, we hope soon to appear, a revised Miller's Checklist of North American Mammals, the only remaining large area to be covered is South America. It is hoped that the staff of the Chicago Natural History Museum might complete and publish a checklist of that continent which was started by the late Wilford H. Osgood.

Ellerman and Morrison-Scott have rendered a great service by bringing to completion a work started by the late James Lawrence Chaworth-Musters, to whom they dedicate the book. The area covered is indicated in the title. A map of the area, in the front of the book, is most useful to those not familar with the geography involved.

In their introduction (p. 1), the authors state that ". . . in writing this work we have thought it worth while attempting a revision rather than making a mere nominal compilation. We have therefore re-examined all relevant monographs and revisions, in so far as they are known to us, together with the extensive study collections of the British Museum, and this checklist represents the results. Whether readers agree with our views or not, we hope that the presentation of such a survey within the covers of one book will prove useful.

"There has been a considerable reduction in the number of named forms regarded as valid, though we have only proceeded with this 'lumping' to the extent that the evidence before us justified it. . . ." The authors recognize 809 species of mammals in the area defined by them. I suspect that many workers will disagree on many points, but this is to be expected. In a work of this magnitude it would be impossible to satisfy all who will use it, however, this does not detract from its value as a reference work.

I am especially pleased at the "common sense" approach to nomenclatorial problems. The following from their introductory remarks will give the reader an idea of their attitude, with which I heartily agree, toward those who would keep our nomenclature in a continuous state of turmoil.

"There are workers who seem to take a delight in bedevilling zoology with esoteric changes in nomenclature, to the considerable irritation of their colleagues and the confusion of non-specialists. In fact, exasperation at their efforts leads many to wonder whether they have any scientific work to attend to."

Some of the "die-hards" will undoubtedly object to the dropping of parentheses from the author's name where the generic name has changed since the original description of the species. This procedure was suggested, in discussion, by the late Dr. Wilford H. Osgood several years ago at an annual meeting of the American Society of Mammalogists. As far as I know, the only two groups in this country who followed his suggestion, although it was against the Rules of the International Commission, were those at the Chicago Natural History Museum and at the University of Michigan Museum of Zoology (Mammals). I hope others will follow the lead and eliminate confusion that results from this antiquated custom. The authors have also followed the recommendation of the International Commission on Zoological Nomenclature in regard to the spelling of scientific names based on surnames (Bull. Zool. Nomen., 4: 205–209, May, 1950). This recommendation has been followed, as editorial policy, in the Journal of Mammalogy, but many North American groups are reluctant to accept it, for what real reason, if any, I do not know.

The authors and the Trustees of the British Museum are to be commended for giving the public this great reference text. It has filled a tremendous gap in our literature.—WILLIAM H. BURT.

Linsdale, Jean M., and Lloyd P. Tevis, Jr. THE DUSKY-FOOTED WOOD RAT: A RECORD OF OBSERVATIONS MADE ON THE HASTINGS NATURAL HISTORY RESERVATION. University of California Press. Berkeley and Los Angeles. x + 664 pp., 384 text figs., 132 numbered tables and several without numbers. 1951. Cloth. Price $7.50.

With the amount of literature that now passes over one's desk, the person who is endeavoring to contribute in a small way to the total knowledge, and at the same time keep informed of progress in his own field of research, is not likely to struggle through some 650 pages of separate accounts of field observations (edited field notes) made by more than twenty different observers over a period of ten years, unless he happens to be doing research on the same subject matter and is thereby obligated to the chore.

As stated in the preface, written by the senior author, "Our purpose . . . in this book is to provide a record of what we have learned here about the wood rat." More than being a "record" there are, scattered through the text, occasional interpretations of observations, but the reader will have to work to find them. It would have been helpful to have known who

was responsible for each of the observations; all one knows is that one of the several observers was the authority for the statement, but the authors must assume the responsibility for its accuracy.

Knowing of the research that has been in progress at the Hastings Reservation, I decided to read the book from cover to cover; I did not succeed. The introductory part and the account of the habitat was fairly easy going. In chapter three I gained a rather good idea of a typical woodrat house and of the normal variation in these structures, after reading the accounts of some twenty different houses. I was then ready for another phase of woodrat activity, but I discovered that there were 52 more separate accounts (numbered) of woodrat houses. Most of these I skipped, and thereby undoubtedly missed some pertinent points buried therein. From the parts which I read, I conclude that woodrats add materials to houses already built and, also, that there is a change of ownership occasionally. Further, an unused house soon deteriorates. I never did learn how the houses got there in the first place, or how a woodrat selects a spot and starts a house.

The next chapter, "Animal Associates," is concerned mostly with parasites. This chapter is well organized, is not repetitious, and contains a wealth of information. On page 127 the authors refer to Table 3, same page, as showing presence or absence of trypanosomes. This table contains nothing on trypanosomes, but Tables 2 and 4 do. Apparently the rats listed in Table 2 (page 125) and in the unnumbered table on page 136 are the same, with a few omitted from the second table, although different number combinations are used in the two tables (rat no. 22 in Table 2 equals no. 46-22 in the second table, etc.). This is also true in other parts of the book and might lead to some confusion. Further, rat no. 27 in Table 2 (p. 125) is given as a female, but no. 27 on page 217 is given as a male. Obviously, they are different rats because one was taken in 1939 and the other in 1946–1947.

Chapter five, "Behavior," contains numerous interesting observations, but again one must make his own interpretations from a series of accounts of separate observations made by different people. On page 229 we read "We observed that the same rat which, on dry leaves, will walk gingerly, picking up its feet one at a time and putting them down slowly and cautiously, will run when it is on branches. . . . Any rapid movement over dry leaves would make crackling sounds and reveal the rat's presence; it would also interfere with the rat's hearing other sounds." Then, on page 233, "More rat sounds were heard at night in May, 1940, than in any previous month that year. These consisted of tail rattling, squealing, and the crackling of dry leaves as the rats moved about in the brush." The two above statements seem not to be in accord; if they are, suggested reasons for the behavior patterns might be expected.

A rather complete list of food items is given in the next chapter. I fail to see, however, the value of the photograph of crumpled leaves on page 287. I would think that it would be difficult even for a botanist to identify some of the leaves from the photo.

Chapter seven, "Reproduction," covers that phase of the life history of the woodrat adequately. There are growth curves and much on behavior, as well as on reproduction proper, in this chapter. The following chapter on morphology contains descriptions of external features and of many of the internal organs of the woodrat. Here we also find many tables and graphs on weights and measurements. The crude outlines of the spleen and kidney, on page 465, do not add to the attractiveness, or value, of the book.

In chapter nine, "Population," the authors attempt to give an overall picture of the population of an area, and to show the gradually changing aspects of that population during the period of study. In this they have done a good job. In addition to strictly population data, this chapter contains information on reproduction and behavior, and more on weights. I suppose there is good reason for printing three practically identical photographs of each area. According to the legends, the photographs were made in different years. As I scrutinize them, they show greater uniformity in vegetation than they do in photographic technique. They do show that there has been practically no change in the habitat from 1939 to 1946, but two halftones would have sufficed for that purpose. Similarly, in the series of portraits of a woodrat on pages 210 and 211, three of the ten poses are so nearly alike that

one must look for the most minute details to distinguish them (center left on p. 210 and upper and lower right on page 211). Even though cost may not be an item in printing a book of this nature, and extra halftones do "dress up" a book, I sincerely believe that each illustration in a scientific publication should show something distinctive. Naturally, I look for a different point to be expressed in each illustration, and I am somewhat frustrated when I can see none, especially when the authors do not explain what the illustration is supposed to demonstrate.

The last chapter, "Conclusions," is a general summary, as well as conclusions, of the main points covered in the text. A statement on page 649, and previously made on page 391, that embryos ranged from one to four is not substantiated by Table 64 (p. 393) where three is the greatest number of embryos recorded. The table "Includes all carcasses examined 1938–1947 except those in epoch 2." Females in epoch 2 were not sexually active. I might add that the column, in Table 64, reading "1–4" should read 1–3 for number of embryos, if the rest of the table is correct.

An index to subject matter is furnished. The page references to "Houses in Long Field" occupy nearly one page, and those to "Rats trapped alive" one and one-half pages. I had occasion to check the usefulness of this elaborate index and found neither no. 46-22 or 46-27 listed. These occur in the text on pages 125 and 126 and in the table on page 136. I did not check further.

The chapter headings in this book are little more than artificial breaking points in the text. If one wishes to know about behavior of the woodrat he will find a chapter devoted to that subject, but he will also find notes on behavior scattered through nearly every other chapter. The same is true of many other topics. There is a profusion of tables and graphs, many showing the same thing, then the same data are presented in the text to make certain that the information won't be missed. This should make it easy for the reader to get the information he wants, but I must confess that I prefer to have my reading material simplified with a minimum of duplication.

The mere gathering and recording of scattered observations, of presumed facts, is in itself not science. It is the foundation material upon which we build our science. These observations, these scattered facts, must be brought into focus, they must be interpreted in the light of our present knowledge. Who should be better qualified to make these interpretations than the very persons who have made the observations, who have gathered the facts?—WILLIAM H. BURT.

Glass, Bryan P. A KEY TO THE SKULLS OF NORTH AMERICAN MAMMALS. Minneapolis. Burgess, 54 pp., 105 figs., 1951, mimeo., spiral binding. Price $2.00.

The title of this manual should have read *A Key to the Skulls of the Genera of North American Land Mammals;* that is what it is. Designed to be used as a laboratory manual, there is a glossary of terms, keys to the genera of land mammals, and a list of general references. The keys are supplemented by line drawings of skulls of all the genera. The drawings are rather crude outlines for the most part, but they serve their purpose. It would be desirable to have more detail in many of them. On the whole, this appears to be a very worth while and usable manual.

As is true in most publications, a few errors get overlooked in the first printing. I shall point out some of these, that I happened to pick up in a rapid perusal, in the hope that they might be corrected in future editions. Page 2: the frontals, I believe, are always paired, although the suture may be closed in early development. "Interorbital breadth" should read 'least interorbital breadth'. Page 3: the canine lies along the suture between the maxillary and the premaxillary, a subtle point. Page 10: one does not see five unicuspids from the lateral view in *Microsorex*. Page 19: the scale for size for the bears is certainly wrong. I suspect it should read cm. instead of mm. Page 40: the grooves on the incisors of *Synaptomys* are not shown; an important character.

My general criticism of the drawings is that, although scales for size are given, it might be slightly confusing to the beginner to see a drawing of a bat and a bobcat of equal size on the same page (p. 18), or that of a polar bear actually smaller than a *Bassariscus* (p. 19).

The reduction or magnification need not be the same for all skulls illustrated on the same page, but I believe a little advance planning so that the illustrations would be a bit more in keeping with the actual sizes of the skulls would add to the value of the manual. The coyote and foxes on page 25 is a good example.

The publishers should put this manual out at about half the price they are now charging. It is on cheap paper and certainly will not stand up with usage.—WILLIAM H. BURT.

Foenander, E. C. BIG GAME OF MALAYA: THEIR TYPES, DISTRIBUTION AND HABITS. London. The Batchworth Press, xvi + 208 pp., illustr. 1952. Cloth. Price 21 s.

Big Game of Malaya is an interesting account of four big game species. Nearly half of the book is devoted to the Malayan gaur or seladang. The author writes in such a manner that he takes the reader with him into the jungles of Malaya in search of big game. One learns about the habits of the largest of wild cattle, the gaur, of the Malayan elephant, the Malayan tapir, and the Sumatran rhinoceros. At the same time he becomes familiar with the country and its people. He sees these magnificant animals at close quarters and shares with the author some of the adventure of stalking them in the thick jungle. Although the author is writing as a sportsman (in the true sense), he is a keen observer of everything around him. He cautiously documents his factual data. Even in some of the "Hunting Stories" the reader will find good Natural History material.—WILLIAM H. BURT.

Young, Stanley P., and Hartley H. T. Jackson. THE CLEVER COYOTE. Harrisburg and Washington. The Stackpole Company and the Wildlife Management Institute, xvi + 411 pp., illustr., 1951. Cloth. Price $6.50.

The Clever Coyote follows the same general style as the two previous books, by Young and Goldman, on the wolves of North America and on the puma. The book is in two distinct parts. Part I, "Its History, Life Habits, Economic Status, and Control," is by Stanley P. Young. The subtitle pretty well indicates the subject material treated in this part. Young is at his best when he is digging into the musty files of historical events. He quotes extensively from various authors, but for some reason one of the most careful studies, Adolph Murie's "Ecology of the Coyote in the Yellowstone," is not mentioned except in the extensive bibliography at the end. Young includes some interesting and pertinent information on tagging results—some individuals will travel more than 100 miles from the place of birth—reproduction, sex ratios, food habits, and many other topics. A quotation from Horn (1941), on page 144, left me wondering a bit. The quotation is as follows: "Coyotes in the foothills of Madera and Fresno Counties feed principally on squirrels and other rodents. Deer are not present. Rodents and rabbits *decreased* [ital. mine] after removal of coyotes, and some species are again increasing." The implication is that if you remove a predatory enemy of a species, then that prey species will decrease in numbers. We might reason, conversely, that to have the greatest number of deer, or sheep, we should encourage their natural enemies. My logic runs out here and I give up.

Young makes a wonderful case against the bounty system, pointing out its impractical and uneconomic aspects as well as the fraudulent practices that are associated with it. I wish that some of our legislators might read this section. In the sections on the economic status, food habits, and control, he presents a strong case against the coyote. After reading the several accounts, and the many quotations, I was beginning to believe that Mr. Coyote was Public Enemy No. 1. When I came to the last paragraph in Young's part of the book I found that the author really had a soft spot in his heart for the subject of the book. He states:

"In summary and final conclusion, therefore, it seems to this author that the coyote, when not an economic liability and therefore requiring local control, has its place as a wilderness animal among North America's fauna. Even the coyote's bitterest enemies amongst men, I feel would admit this, if for no other than an esthetic desire to hear its yap with the setting of the western sun. The West would never be the West, should this Gothic-like creature, all in points, become entirely extirpated."

Part II, "Classification of the Races of the Coyote," is by Hartley H. T. Jackson. This is a purely taxonomic study. Jackson recognizes 19 subspecies of the one species, *Canis*

latrans, in North and Central America. He states that he has been conservative in his treatment. This is understandable in dealing with such a wide-ranging animal. When we note (p. 75) that individual coyotes may travel up to 400 miles, then glance at the distribution map (p. 255) and see several ranges of subspecies less than 200 miles across, with no obvious barriers to coyotes, we may wonder. However, I trust Dr. Jackson's judgement and shall accept his interpretations.

There is one item (p. 303) that should be corrected. The type locality of *Canis latrans jamesi* is given as "Tiburon Island, Baja California." Tiburon Island lies against the Sonora Coast and, I believe, is considered a part of that state, not Baja California. The island lies farther north than it is shown on the map (p. 255), at about 29° north latitude.—WILLIAM H. BURT.

Higman, Harry W., and Earl J. Larrison. UNION BAY: THE LIFE OF A CITY MARSH. Seattle. Univ. of Washington Press, x + 315 pp., 1951. Price $4.00.

Union Bay is a delightful story of the animal life of a marsh within the confines of a busy city. Written in a popular manner for popular consumption the book contains more good information on natural history (ecology) than most "scientific" studies of given areas. Accounts of the "goings on" within the confines of the marsh are concerned mostly with the different kinds of birds, but mammals play a definite part in the drama, and comedy. The scene always has the same setting, but each chapter is a new and different act. Authors and publisher are to be commended on the production of this attractive, informative volume. —WILLIAM H. BURT.

RECENT LITERATURE

(Conducted by G. S. Miller, Jr., Emma Charters, D. H. Johnson, and R. H. Manville)

[Reprints of this section may be purchased from the Corresponding Secretary]

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THIRTY-SECOND ANNUAL MEETING

THIRTY-SECOND ANNUAL MEETING OF THE AMERICAN SOCIETY OF MAMMALOGISTS

APRIL 14–18, 1952

The thirty-second annual meeting of the American Society of Mammalogists was held at the College of Charleston, Charleston, South Carolina, April 14–18, 1952. Sessions were held in the Memminger Auditorium and the College of Charleston Chapel. There were field trips to Bull's Island and Edisto Beach on April 18.

The local committee on arrangements consisted of: R. H. Coleman, *Chairman*, W. P. Baldwin, E. M. Burton, E. B. Chamberlain, G. D. Grice, E. D. Jennings, R. G. Tunz, and A. Sprunt.

PROGRAM

MONDAY, APRIL 14

8:30 P.M.

Directors' Meeting, Fort Sumter Hotel

TUESDAY, APRIL 15

8:30 A.M.

Registration, Memminger Auditorium

9:00 A.M.

Welcome. Harold A. Mouzon, *President, Board of Trustees, College of Charleston.*

Response. William J. Hamilton, Jr., *President, American Society of Mammalogists.*

1. An eight year history of *Sigmodon* population at Athens, Georgia. Eugene P. Odum, *University of Georgia, Athens.*
2. Some habitat responses of the cotton rat, *Sigmodon hispidus*. Jack M. Inglis, *Texas A. and M. College, College Station, Texas.* By title.
3. A study of the home range of the cotton rat, *Sigmodon hispidus*. Joseph C. Howell, *University of Tennessee, Knoxville.*
4. An invasion of Norway rats into southwest Georgia. Dean H. Ecke, *U. S. Public Health Service, Thomasville, Georgia.*
5. Observations on lemmings at Barter Island, Alaska. Frederick S. Barkalow, Jr., *North Carolina State College, Raleigh.*
6. A note on the response of *Microtus* to vegetative cover. W. Robert Eadie, *Cornell University, Ithaca.*
7. Preliminary investigations on the life history of the Arctic ground squirrel, *Citellus parryi*. William V. Mayer, *University of Southern California, Los Angeles.*
8. The status of the coati-mundi in Arizona. O. C. Wallmo, *Texas A. and M. College, College Station.* By title.

Remarks by Ernest P. Walker on the utilization of zoo specimens.

12:00 NOON

Annual Group Photograph

2:00 P.M.

9. Variation in spotted skunks in southeastern United States. Richard G. Van Gelder, *University of Illinois, Urbana.*
10. Subspeciation in terminal populations. Stephen D. Durrant, *University of Utah, Salt Lake City.*

11. Taxonomic differences and phylogenetic trends in the meibomian glands of microtines. W. B. Quay, *University of Michigan, Ann Arbor.*
12. Notes on geographic variation in the genus *Alces*. R. L. Peterson, *Royal Ontario Museum, Toronto.*
13. Geographic variation of the *Peromyscus boylei* group in Texas and Oklahoma. William K. Clark, *University of Richmond, Virginia.*
14. New mammals of the Rexroad fauna. Claude W. Hibbard, *University of Michigan, Ann Arbor.*
15. The dentition of rabbits and the origin of the Lagomorpha. Loris S. Russell, *National Museum of Canada, Ottawa.*
16. The research potentialities of the North American census of small mammals. John B. Calhoun, *Army Medical Graduate School, Washington, D. C.*

5:00 P.M.

A Tea for the Ladies, College of Charleston Library

8:00 P.M.

Informal Social, Charleston Museum

WEDNESDAY, APRIL 16

8:30 A.M.

17. The distribution and relative abundance of the black bear in Virginia. L. B. Davenport, Jr., *University of Georgia, Athens.*
18. The status of important game and fur-bearing mammals in Georgia. James H. Jenkins, *University of Georgia, Athens.*
19. Experimental traplines in northern Ontario. A. de Vos, *Ontario Division of Fish and Wildlife, Maple.*
20. Applied animal ecology—an immediate challenge and a future necessity. Clifford C. Presnall, *U. S. Fish and Wildlife Service, Washington, D. C.*
21. The fisher in New York State. William J. Hamilton, Jr., *Cornell University, Ithaca.*

10:00 A.M.

Annual Business Meeting, Election of Officers

2:00 P.M.

Symposium on Economic Mammalogy, Robert A. McCabe, *Chairman*

22. The economics of small rodent populations. Don W. Hayne, *Michigan State College, Lansing.*
23. The economic values of certain fur animals in North Carolina. Kenneth A. Wilson, *North Carolina Wildlife Resources Commission, Currituck.*
24. The cottontail rabbit as an economic resource of Missouri. William H. Elder, *University of Missouri, Columbia.*
25. The red fox and its economy in the midwest. Thomas Scott, *Illinois Natural History Survey, Urbana.*
26. Population trends of predators and fur animals in 1080 station areas. Weldon B. Robinson, *U. S. Wildlife Research Laboratory, Denver.*
27. The economics of a deer herd. Robert A. McCabe, *University of Wisconsin, Madison.*

6:00 P.M.

Annual Dinner, Fort Sumter Hotel
The Gullah Story, by Samuel G. Stoney

8:30 P.M.

The Society for the Preservation of Spirituals
Dock Street Theater, 135 Church Street

THURSDAY, APRIL 17

28. The status of the American bison in 1951. Henry H. Collins, Jr., *Bronxville, N. Y.* Read by Ralph S. Palmer.
29. Influence of the injection of air, oil, and water into dormant estivating mammals. Arthur Svihla, *University of Washington, Seattle.*
30. "Shock disease" in captive wild mammals. John J. Christian and H. L. Ratcliffe, *Philadelphia Zoological Society and University of Pennsylvania, Philadelphia.*
31. The hooded seal in Pennsylvania waters. Frederick A. Ulmer, Jr., *Philadelphia Zoological Society, Philadelphia.*
32. Studies of the Douroucouli language. Ernest P. Walker, *National Zoological Park, Washington, D. C.*
33. Notes on the pigmy sperm whale. Henry Kritzler, *Duke University Marine Laboratory, Beaufort.*
34. Hibernation in the big brown bat. James Beer, *University of Minnesota, St. Paul.*
35. Speciation and distribution in the genus *Phalanger* (Marsupialia). G. H. H. Tate, *American Museum of Natural History, N. Y.*
36. Display and detection of post-parturitional heat in the female adults and new-born of the golden hamster, *Cricetus auratus*. A. L. Soderwall and G. K. Armen, *University of Oregon, Eugene.* By title.
37. Techniques for studying mammalian sex reaction data. Albert R. Shadle and Robert W. Weigel, *University of Buffalo.*
38. Relationships of the cricetine genera *Sigmodon, Oryzomys, Peromyscus,* and *Neotoma:* a comparative myological study. George C. Rinker, *University of Michigan, Ann Arbor.*
39. Some tentative conclusions on reproduction in two genera of Heteromyidae, based on histological observations. Kenneth L. Duke, *Duke University, Durham.*
40. Antelope populations in relation to solar radiation and moisture. V. E. Shelford, *University of Illinois, Urbana.* Read by J. F. Opsahl
41. Analysis of home range from recapture data. David E. Davis, *Johns Hopkins University, Baltimore.*

2:00 P.M.

42. Age variation in meadow mice from Pennsylvania. Dana Snyder, *Carnegie Museum, Pittsburgh.*
43. An example of bias in external measurements. John E. Guilday, *Carnegie Museum, Pittsburgh.*
44. Should we name minute geographic variations? J. Kenneth Doutt, *Carnegie Museum, Pittsburgh.*
45. African parks and wildlife. Victor Cahalane, *U. S. National Park Service, Washington, D. C.*

4:00 P.M.

Final Business Meeting, College of Charleston Chapel

FRIDAY, APRIL 18

The members and guests were invited to attend field trips to Bull's Island and Edisto Beach.

BUSINESS MEETING

The meeting of the Board of Directors was called to order by President William J. Hamilton, Jr. W. K. Gregory was reelected a Trustee to succeed himself for another three years. W. Robert Eadie was elected Editor. The reports of the Treasurer, Auditing Committee, and Trustees were read and accepted. Owing to the increase in printing costs, the price of subscriptions to the Journal was raised to $6.00. Budgetary allotments were made

for the year and the Society's memberships in the International Union for the Protection of Nature and the American Institute of Biological Sciences were renewed.

The annual business meeting on April 16 was attended by 66 members. The reports of the Corresponding Secretary, Treasurer, and Trustees were read. The following officers were elected: William J. Hamilton, Jr., *President;* William H. Burt and William B. Davis, *Vice-presidents;* Randolph L. Peterson, *Recording Secretary;* Keith R. Kelson, *Corresponding Secretary;* and Viola S. Schantz, *Treasurer*. Directors for the term 1952–1954 were elected as follows: Donald F. Hoffmeister, Robert T. Orr, Stephen D. Durrant, Robert H. Coleman, and George H. H. Tate. Joseph C. Moore was elected to fill the unexpired 1951–1953 term vacated by W. Robert Eadie.

With deep regret the Society learned of the death of 5 members, one a Charter Member (*), in 1951: *Sherman C. Bishop, Gus A Engeling, H. E. Ewing, J. S. Y. Hoyt, and Deane W. Mather.

The year 1951 witnessed the growth of the Society in all respects. There were 143 nominees for membership, 2 conversions from Annual to Life Membership, 29 resignations, 5 deaths reported, and 59 persons dropped from membership for delinquency in dues for three years. The campaign to obtain new subscribers resulted in 71, but 50 others dropped their subscriptions. The principal lag in the Society's affairs is the small number of Life Memberships. Members and nominees are urged to consider Life Memberships which are highly desirable both from the standpoint of the individual and the Society.

The Corresponding Secretary submitted the following summary of memberships, subscriptions, and mailing for the year ending December 31, 1951.

SUMMARY OF MEMBERSHIPS AND SUBSCRIPTIONS FOR 1950 AND 1951

	1950		1951	
MEMBERSHIP				
Changes since preceding annual report				
Nominees		130		143
Resignations	26		29	
Deaths reported	8		5	
Members dropped (delinquent)	30		59	
Total		64		93
Net Change		+66		+50
Status as of December 31				
Honorary members	3		5	
Life members	48		50	
Annual members	1247		1293	
Total membership		1298		1348
SUBSCRIPTION				
Changes since preceding report				
New subscriptions	45		71	
Subscriptions cancelled	18		50	
Net Change		+27		+21
Status as of December 31				
Total paid subscriptions		410		431
MAILING LIST				
Total membership	1298		1348	
Members not receiving Journal	126		130	
Total members receiving Journal		1172		1218
Total paid subscriptions		410		431
Total mailing list		1582		1649
Net change from preceding year		+96		+67

FINAL BUSINESS MEETING

The final business meeting was held April 17. Forty-five members were present. For distinguished service to mammalogy, two persons were unanimously elected to honorary membership: Hartley H. T. Jackson and Edward A. Preble.

The reports of the following committees were read and accepted: Conservation of Land Mammals (Ralph S. Palmer); Bibliography (submitted by David H. Johnson, read by Donald F. Hoffmeister); Marine Mammals (Robert T. Orr); Economic Mammalogy (submitted by E. R. Hall, read by the Chair); Nomenclature (submitted by C. C. Sanborn, read by Donald F. Hoffmeister); Membership (A. R. Shadle); Honoraria (George H. H. Tate). Reports of representatives to other societies were read.

Following the report of the representative to the National Resources Council, considerable discussion ensued, and the Society voted to endorse the Council's statement in principle. Wilbur B. Quay, recipient of the honorarium for young mammalogists for 1951, was introduced to the Society.

An invitation from H. E. Anthony to have the Society meet in New York in 1953 was read, and the invitation accepted. The Society, by vote, expressed a desire that the 1953 meeting be held in June, and concurrently with the meeting of the American Society of Ichthyologists and Herpetologists.

Antoon de Vos suggested consideration of an Associate Membership class. The matter was referred to the Membership Committee.

The following resolution was unanimously passed:

Whereas the Charleston College and its entire staff, and members of the local committee, especially R. H. Coleman and G. D. Grice, and

Whereas the Charleston Museum and its Directors, the Society for the Preservation of Spirituals, and the Charleston Chamber of Commerce have made facilities possible and have provided unexcelled entertainment that has made the Thirty-second Annual Meeting of this Society such an outstanding success and signal event

Therefore be it resolved that the American Society of Mammalogists extends to the aforementioned organizations and individuals its grateful thanks and appreciation for the enjoyable and profitable time spent in their midst.

COMMENT AND NEWS

NEW JOURNALS

The Society of Systematic Zoology is now publishing a Journal called SYSTEMATIC ZOOLOGY. Volume 1, number 1, was issued in the spring of 1952. This is to be a quarterly journal, and will carry articles of general interest to all systematists in zoology, according to the announcement. In addition to the main articles, there will be book notices and news items. Subscription rates are $4.00 per annum to members and $7.00 per annum to nonmembers and institutions. Correspondence should be directed to Dr. R. E. Blackwelder, Room 429, U. S. National Museum, Washington 25, D. C.

A new German Journal, SÄUGETIERKUNDLICHE MITTEILUNGEN, will have as headquarters München. The price will be about 12 DM. Manuscripts on zoogeography, anatomy, and paleontology should be sent to Dr. Theodor Haltenorth, München 38, Menzinger Str. 67. Those on ecology, physiology, or psychology should be sent to Prof. Dr. H. Kahmann, München 2, Luisenstrasse 14, Zool. Inst. der Universität.

DEATHS

Deaths, recently reported, of members of the Society are as follows: **Herbert Lawrence Dozier,** December 4, 1951; **Gus A. Engeling,** December 13, 1951; **Charles W. Goodrum,** January 28, 1950; **Deane W. Mather,** September 28, 1951.

DATE OF ISSUE OF PREVIOUS NUMBER

Journal of Mammalogy, Vol. 33, No. 2, was mailed May 16, 1952

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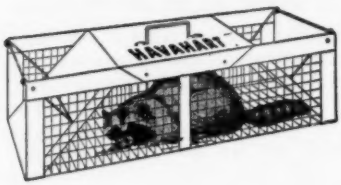

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